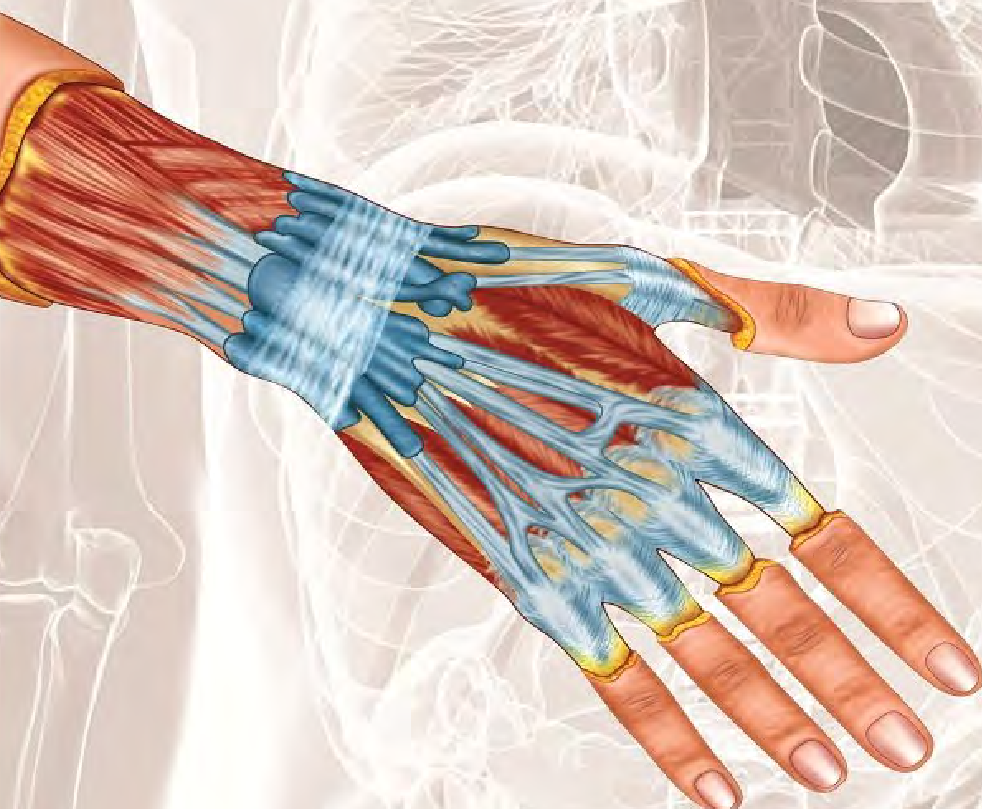
Inderbir Singh's **Textbook of**

ANATOMY



Volume One

General Anatomy
Upper Limb
Lower Limb

6th Edition

Edited by
Sudha Seshayyan

JAYPEE

Volume I

Inderbir Singh's

TEXTBOOK OF ANATOMY

Sixth Edition

VOLUME I

VOLUME II

VOLUME III

Volume I

Inderbir Singh's

TEXTBOOK OF ANATOMY

ANATOMY

Sixth Edition

Revised and Edited by

Sudha Seshayyan MS PDHM

Director and Professor
Upgraded Institute of Anatomy
Vice Principal, Madras Medical college
Chennai

JAYPEE *The Health Sciences Publisher*

New Delhi | London | Philadelphia | Panama

Jaypee Brothers Medical Publishers (P) Ltd

Headquarters

Jaypee Brothers Medical Publishers (P) Ltd
4838/24, Ansari Road Daryaganj
New Delhi 110 002, India
Phone: +91-11-43574357
Fax: +91-11-43574314
Email: jaypee@jaypeebrothers.com

Overseas Offices

J.P Medical Ltd
83 Victoria Street, London
SW1H 0HW (UK)
Phone: +44 20 3170 8910
Fax: +44 (0)20 3008 6180
Email: info@jpmedpub.com

Jaypee-Highlights Medical Publishers Inc
City of Knowledge Bld. 237, Clayton
Panama City, Panama
Phone: +1 507-301-0496
Fax: +1 507-301-0499
Emai : cservice@jphmedical.com

Jaypee Medical Inc
The Bourse
111 South Independence Mall East
Suite 835, Philadelphia, PA 19106, USA
Phone: +1 267-519-9789
Email: jpmed.us@gmail.com

Jaypee Brothers Medical Publishers (P) Ltd
17/1-B Babar Road, Block-B, Shaymali
Mohammadpur, Dhaka-1207
Bangladesh
Mobile: +08801912003485
Email: jaypeedhaka@gmail.com

Jaypee Brothers Medical Publishers (P) Ltd
Bhotahity, Kathmandu, Nepal
Phone: +977-9741283608
Email: kathmandu@jaypeebrothers.com

Website: www.jaypeebrothers.com
Website: www.jaypeedigital.com

Inquiries for bulk sales may be solicited at: jaypee@jaypeebrothers.com

Textbook of Anatomy

First Edition : 1996
Second Edition : 1999
Third Edition : 2003
Fourth Edition : 2007
Fifth Edition : 2011
Sixth Edition : **2016**

ISBN 978-93-5152-963-7

Printed at

Late Professor Inderbir Singh
(1930–2014)

Tribute to a Legend

Professor Inderbir Singh, a legendary anatomist, is renowned for being a pillar in the education of generations of medical graduates across the globe. He was one of the greatest teachers of his times. He was a passionate writer who poured his soul into his work. His eagle's eye for details and meticulous way of writing made his books immensely popular amongst students. He managed to become enmeshed in millions of hearts in his lifetime. He was conferred the title of Professor Emeritus by Maharishi Dayanand University, Rohtak.

On 12th May, 2014, he was awarded posthumously with* Emeritus Teacher Award *by* National Board of Examination *for making invaluable contribution in teaching of Anatomy. This award is given to honour legends who have made tremendous contribution in the field of medical graduate. He was a visionary for his times, and he legacies he left behind are his various textbooks on *Gross Anatomy*, *Histology*, *Neuroanatomy* and *Embryology*. Although his mortal frame is not present amongst us, his genius will live on forever.

Preface

Castles of all medical wisdom are anchored to the knowledge of anatomy. Both the learning and the teaching of anatomy have undergone masterly changes. Though the limits of human anatomy appear to be confined to the boundaries of the human body, newer frontiers have constantly appeared due to two primary factors—one, expanding basic medical and clinical research and two, larger understanding of hitherto unexplained areas.

The preparation of a textbook on Anatomy should have the scope to adequately accommodate the growing changes. At the same time, it also cannot become disproportionately large, considering the time span within which an average undergraduate medical student would have to acquire this knowledge.

This edition of Inderbir Singh's *Textbook of Anatomy* has been prepared keeping the twin factors of the restructuring of medical curriculum and the knowledge expansion in mind. Many of the chapters have been completely revised and rewritten. Clinical Correlation has been clearly laid out. Embryological and Histological details have been added so as to give the reader a comprehensive picture. Newer features like Multiple Choice Questions and Clinical Problem-solving have been appended to each chapter in order to provide the reader with the opportunity of self-assessment

A student entering the medical curriculum is faced with a completely new atmosphere. In an attempt to familiarize the student not only with Anatomy but also with the nuances of the medical world, new sections on *General Anatomy* and *Genetics* have been added. Professor Inderbir Singh's eye for details and meticulous writing style have always been popular amongst generations of medical students. Though many areas of the book have been revisited, the basic spirit and nature of the book have been retained. Additional features like *Added Information* and *Clinical Correlation* in any chapter will be of much help not only to the undergraduate students but also to the postgraduates.

At this juncture, I would like to place on record my appreciation and gratitude to Dr Hannah Sugirthabai Rajila Rajendran, Professor, Department of Anatomy, Chettinad Hospital and Research Institute, Kanchipuram District, Tamil Nadu, India; Dr M Nirmaladevi, Associate Professor, PSGIMS & R, Coimbatore, Tamil Nadu, India and Dr J Sreevidya, Assistant Professor-cum-Civil Surgeon, Madras Medical College, Chennai, Tamil Nadu, India for their painstaking editorial assistance. I would like to thank Dr Indumathi. S, Professor and HOD, Department of Anatomy, Chettinad Hospital and Research Institute, Dr T Anitha, Dr Elamathi Bose and Dr Bhuvaneswari, Assistant Professors of Anatomy, Madras Medical College, Chennai for their help during the preparation and review of the manuscripts and formulation of chapters.

I would be failing in my duty if I do not acknowledge the contributions of Dr Lakshmi, Dr Kanagavalli, Dr Arrchana, Assistant Professors, Department of Anatomy, Madras Medical College, Chennai and Dr Dharani, Assistant Professor, Villupuram Government Medical College, Villupuram, Tamil Nadu, India towards the completion of this edition. Shri RAC Mathews, Shri Ranganathan and Shri Sashikumar were instrumental in providing the necessary assistance, and Shri E Senthilkumar provided some of the illustrations for the book and I would like to extend my thanks to each of them.

Special thanks to Shri Jitendar P Vij (Group Chairman) and Mr Ankit Vij (Group President), Jaypee Brothers Medical Publishers (P) Ltd., without whom this edition would not have seen the light of the day. I am extremely thankful to them for reposing their confidence in me and providing the opportunity to revise Inderbir Singh's *Textbook of Anatomy*. Dr Sakshi Arora (Director, Content and Strategy) has been the driving force behind all efforts and deserves a very special thanks. She has provided insights and inovative ideas which have gone a long way in consolidating this book to best meet the needs of the taught and the teacher alike. We are thankful to her entire Development and Content Strategy team consisting of Ms Nitasha Arora (Project Manager), Ms Ankita Singh, Ms Sonal Jain, Ms Neelam Kakariya, Mr Prashant Soni (Editorial), and Mr Prabhat Ranjan, Mr Neeraj Choudhary, Mr Bunty Kashyap, Mr Phool Kumar, Mr Puneet Kumar, Mr Vikas Kumar, Mr Sanjeev Kumar and Mr Sandeep Kumar (Designers and Operators) for their constant technical support throughout the project.

This book is the combined effort of a number of people who have contributed in myriad ways and it may not be humanly possible to list down the many; however, I take this opportunity to extend my thanks to all of them.

Sudha Seshayyan

Contents

Section 1 General Anatomy

Section 2 Upper Limb

Section 3 Lower Limb

Section 1

General Anatomy

Chapter 1

Science of Anatomy

Frequently Asked Questions

- Define normal anatomical position.
- Describe the three perpendicular planes of the body.
- Write short notes on flexion and extension.

Anatomy is the science that deals with the structure of the body. This name was given by Aristotle about 2300 years ago. Study of the structure of living beings was done by dissecting the body and seeing the various structures in position; hence, the term ***anatomy*** (ana+tome=cutting up) was given. The term applies to the study of the structure of all living beings; specificity is given by adding a prefix that indicates the area of study. ***Plant anatomy*** is study of the structure of plants; ***veterinary anatomy*** is study of structure of animals; ***equine anatomy*** is study of structure of horses. Study of structure of the human body is called ***human anatomy.***

The scope of the subject has widened very much and several subdivisions are now studied. These subdivisions include:

- ***Gross anatomy*** or ***morphological anatomy*** or ***macroscopic anatomy:*** Study of structures which can be seen by naked eye (Greek.macro=large; skopein=to watch; morphe=form/shape);
- ***Microscopic anatomy*** or ***histology:*** Study of structures which can be seen only on magnification, like under a microscope. Histology can also be defined as study of tissues, since tissues are microscopic. Further subdivision is ***ultrastructural anatomy*** which is study of tissues using higher magnification like the electron microscope (Greek.micros=small; histos=tissue);
- ***Cytology:*** Study of details of the structure of cells (Greek kytos=cell);
- ***Embryology*** or ***developmental anatomy:*** Study of growth and development of body structures before birth (Greek.embryo=to grow);
- ***Regional anatomy*** or ***Topographical anatomy:*** Study of various structures in relation to their location and relationship to the adjacent structures;
- ***Systemic anatomy:*** Study of the various organ systems of the body;
- ***Cadaveric anatomy:*** Study of dead and preserved bodies;
- ***Living anatomy:*** Study of anatomy in a living individual by using simple techniques like palpation, percussion and auscultation or higher techniques like endoscopy, radiography and electrography.

  It can well be seen that areas like radiological anatomy and clinical anatomy form part of living anatomy.

Dissection

Anatomy, from time immemorial, has been studied by the use of dead bodies which are preserved by chemical means. The bodies are methodically dissected region by region and the various structures, their positions and relations are noted. Gross anatomy, regional anatomy and systemic anatomy are subdivisions of such a study. Embryology is also studied by dissecting dead foetuses.

With advancements in medicine, it is now possible to visualise internal structures without cutting open the body, even in a living individual. In fact, such techniques can be done properly only if there is sound knowledge of anatomy. Lacuna in anatomical knowledge while performing such techniques can lead to damage of structures and in turn, other complications. On the other hand, by using such techniques, knowledge of anatomy can be refined and intricate details added.

- ***Functional anatomy:*** Study of the structural basis of the functions of various structures and the interrelationships of various organ systems;
- ***Applied anatomy*** or ***clinical anatomy:*** Study of aspects of anatomy that play a role in disease, diagnosis of disease and treatment;
- ***Cross-sectional anatomy:*** Study of body structures with special reference to cross-sections of the body at different levels;
- ***Surface anatomy:*** Study of surface projections of internal structures with special reference to accessing them easily (the name topographic anatomy can also be applied to this since the internal topography is marked on the surface);
- ***Radiological anatomy*** or ***imaging anatomy:*** Study of structures as they appear in imaging pictures like X-rays, CT scans, ultrasound images and MRI scans;
- ***Histochemistry:*** Study of chemical processes that take place in cells and tissues;
- ***Experimental anatomy:*** Study of factors which influence and control the structure and functions of different parts of the body;
- There are areas which are closely allied to anatomy but also deserve separate specialisation. These include:
  - ***Genetics:*** Study of chromosomes and genes;
  - ***Anthropology:*** Study of the features of different groups and races of human. This is now specifically called physical anthropology, since areas like social and economic anthropology have also evolved.

DESCRIPTIVE TERMS

Study of 'Anatomy' is fundamental and essential to all subsequent studies in medical education. Anatomical terms are used in every other speciality of medical curriculum. Terms like 'in front', 'behind', 'above', 'below', and so on, which are used in describing structures are not scientific terms and can lead to ambiguity if improperly used Hence, scientific and definitive terms are needed.

Anatomical Position

While describing structures of the human body, it is necessary to have uniformity of terms to avoid confusion and ambiguity. Hence, all descriptions are done with reference to a standard position called the ***normal anatomical position (Fig. 1.1)***. The human body is regarded as standing upright, eyes looking directly forwards (to a distance), feet parallel to each other and toes directed forwards, with the arms held by the sides of the body and with the palms facing forwards. The cadaver, during dissection may be lying on its back, on its side or on its face; whatever, it should be assumed to be in anatomical position and all descriptions and studies made with reference to this position. Similarly, the living patient may be in any position during examination or treatment; but all references to body structures should be in anatomical position

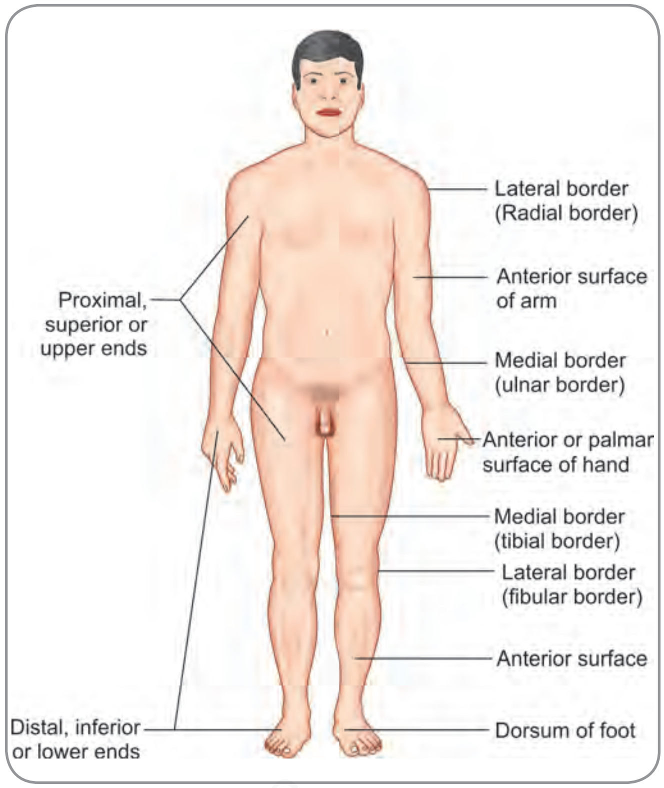


Fig. 1.1: Normal anatomical position

Whether it is dissection of the cadaver or examination of a living individual, two other positions frequently adopted are the supine and prone positions. In the supine position, the individual lies on the back with the upper limbs placed by the side of the trunk, palms facing upwards and feet together. In the prone position, the individual lies on the chest and belly with the face downwards and upper limbs on the side of the trunk.

Planes of the Body

As the human body is a three-dimensional (3D) structure, three perpendicular planes are described.

- The plane passing vertically through the midline of the body, so as to divide the body into right and left halves, is called the ***median plane***. It is also called the ***mid-sagittal plane***, since it is parallel to the sagittal suture of the skull (Fig. 1.2);
- Vertical planes to the right or left of the median plane, and parallel to the latter, are called ***paramedian*** or ***parasagittal planes*** (or plainly the ***sagittal planes***) (Fig. 1.2);
- The vertical plane placed at right angles to the median plane, but dividing the body into anterior and posterior

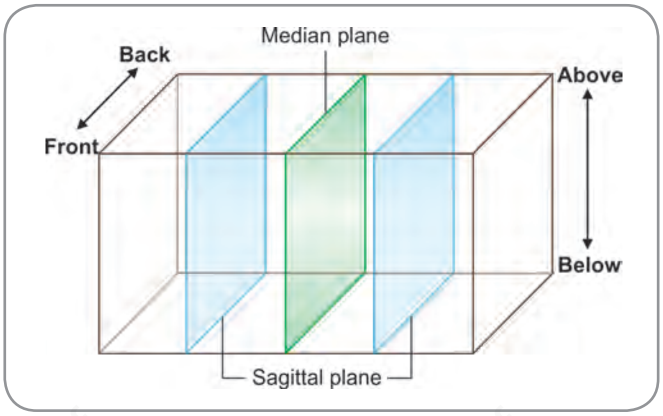


Fig. 1.2: Scheme showing median and sagittal planes

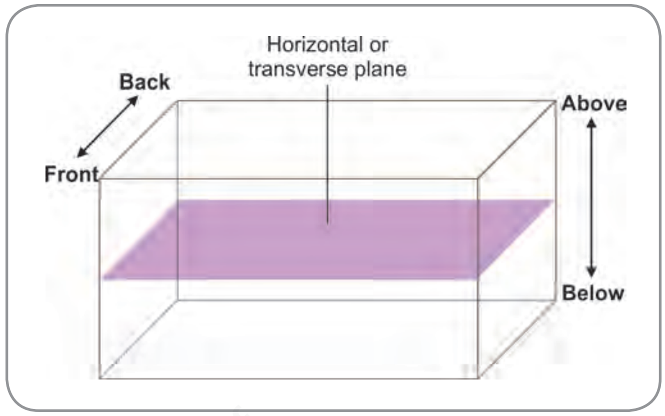


Fig. 1.4: Scheme showing a horizontal or transverse plane

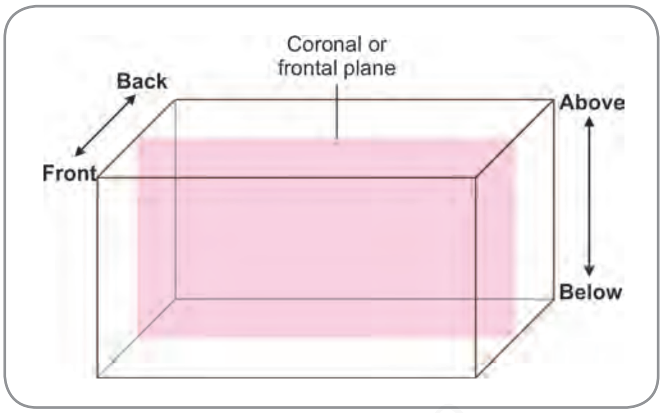


Fig. 1.3: Scheme showing a coronal or frontal plane

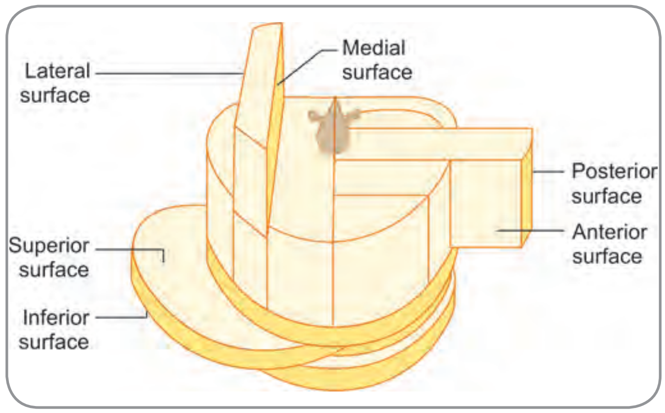


Fig. 1.5: Surfaces of body

parts, is called a ***coronal plane*** or a ***frontal plane*** (Fig. 1.3). It is parallel to the coronal suture of the skull;

- Planes passing horizontally across the body, at right angles to both the sagittal and coronal planes and dividing it into upper and lower parts, are called ***transverse*** or ***horizontal planes*** (Fig. 1.4). In the case of a limb, a transverse section is any section at right angles to the long axis of the limb. Similarly, the transverse section of an organ is at right angles to the long axis of the particular structure.
- An ***oblique plane*** is at any other angle.

Terms of Location and Relationship (Fig. 1.5)

To describe various structures with reference to each other, several terms are required. Of these, three pairs of terms are basic and important. These are as follows:

1. ***Anterior–posterior:*** Anything nearer or closer to the front is ***anterior***; anything nearer or closer to the back is ***posterior*** (Fig. 1.5).
2. ***Superior–inferior:*** Anything nearer or closer to above is ***superior*** (nearer the top of head); anything nearer or closer to below is ***inferior*** (nearer the sole of feet) (Fig. 1.5).
3. ***Medial–lateral:*** Anything nearer or closer to the centre or the midline of the body is ***medial***; anything farther from the midline is ***lateral*** (Latin.medius=middle; latus=side) (Fig. 1.5).

The vertical plane passing through the midline of the body, as already been described, is the median plane (Fig. 1.2). Any structure lying in the median plane is described to be ***median*** in position

It can be clearly seen that the above mentioned three sets of terms correspond to the three fundamental perpendicular planes of the body.

Structure **A** in figure 1.6 is nearer to the front of the body as compared to structure **B**; hence **A** is said to be ***anterior*** to **B** and **B** is posterior to **A.** If **Z** is taken into account, Z is anterior to **B** and posterior to **A**. Structure **C** lies nearer the upper end of the body as compared to structure **D**; hence **C** is said to be ***superior*** to **D** and **D** is inferior to **C**.

When a structure lies in the median plane it is said to be ***median*** in position. As shown in the figure 1.7, structure **E** lies nearer to the median plane than structure **F**; hence **E** is said to be ***medial*** to **F** and **F** is lateral to **E**.

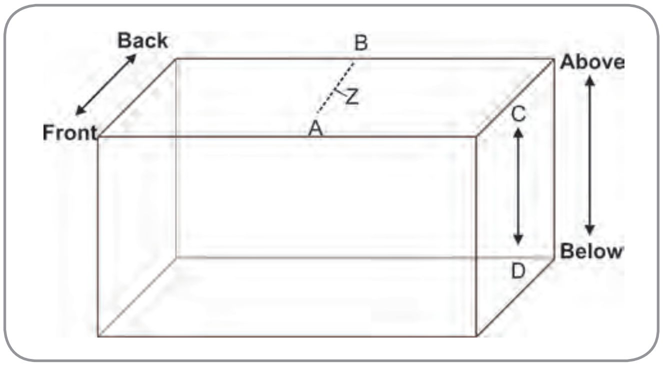


Fig 1.6: Scheme to explain the terms anterior–posterior, superior–inferior

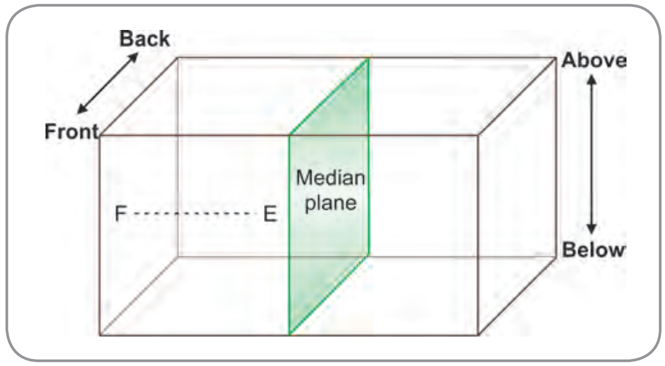


Fig. 1.7: Scheme to explain the terms medial, lateral and median

Other Terms of Description

There are several other terms which are used frequently to indicate location, shape, size and relations of a structure. The following list shows these terms.

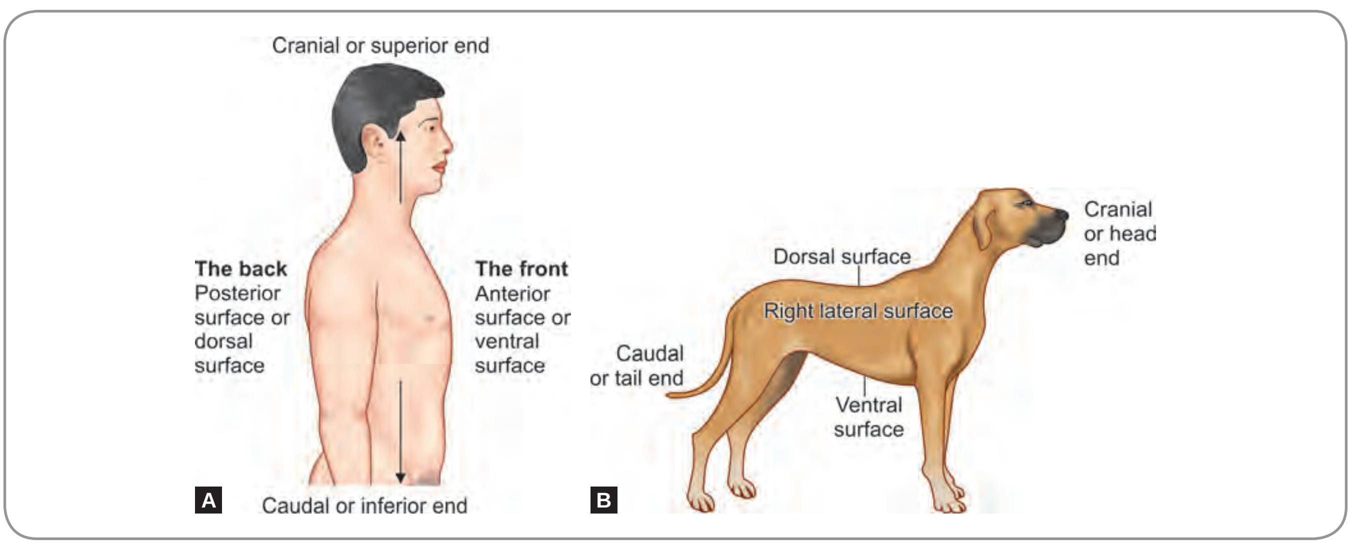
- ***Ventral:*** Closer to or on the belly side of the body (Latin. venter=belly);
- ***Dorsal:*** Closer to or on the back surface of the body (Latin.dorsa=back).

At first look, it appears that the terms ***ventral*** and ***dorsal*** can be used synonymous to ***anterior*** and ***posterior***. Very often they are, especially with regard to the human body However, let us think of a comparative situation. In human beings, the heart an be described to be superior (above) to the diaphragm; in quadruped animals, like the cat or the dog, the heart is anterior (in front) to the diaphragm. But in both instances, the position of the heart relative to the other structures of the body remain the same. To avoid confusion in such comparative descriptions (which are required in comparative and experimental studies and especially in embryology), the terms ***ventral*** and ***dorsal*** are used. Anything closer to the belly side will be ***ventral*** (venter – belly) and anything closer to the back will be ***dorsal*** (dorsum – back) (Figs 1.8A and B).

The terms ***cranial*** and ***caudal*** are also used. Anything closer to the head or towards the head is cranial (cranium – head; Greek.kranion=skull) and anything closer to or towards the tail portion is 'caudal' (Latin cauda=tail). ***Cephalic*** is a term used as a substitute to cranial and means towards the head. These terms are routinely used in embryology and it is preferable to use them in gross anatomy too.

With regard to the limbs of the body, the terms superior and inferior are sometimes replaced by another set of terms: ***proximal*** and ***distal*** (Fig. 1.1). Proximal is anything closer to the root (or point of origin; Latin.proximus=nearest) and distal is anything away from the root (more distant; Latin. distare=to be distant). This can be noted in the naming of the phalanges of the hands; the phalanges close to the base of the fingers are proximal, those close to the tips are distal and those between the two are middle.

There are also other sets of terms used with reference to the limbs. As the palms face forwards in the normal anatomical position, the upper limb can be described to have a ***medial border*** (Fig. 1 1) (one that is close to the body trunk) and a ***lateral border*** (Fig. 1.1) (one that is away



Figs 1.8A and B: Anatomical terms—terms of ocation

from the body trunk). Since the ulna bone of the forearm is on the medial aspect and the radius bone on the lateral aspect, the medial and lateral borders are called the ***ulnar*** and ***radial borders***. A similar situation can be seen in the lower limb too. The tibia of the leg is medial and the fibula is lateral; hence, the medial border is called the ***tibial border*** and the lateral border is the ***fibular border***. The anterior surface of the hand (one related to the palm) is ***palmar*** or ***volar***; the inferior surface of the foot is ***plantar***; the opposites of both these, namely, the posterior surface of hand and the upper surface of foot are ***dorsal***.

> Many more terms are being used regularly. A list of important terms are given below:
> - ***Superficial:*** Close to the skin surface, nearer to skin
> - ***Deep:*** Remote to the skin surface
>
> The terms superficial and deep are not in relation to the anatomical position and are used in relation to the approach during study.
> - ***Internal:*** Inner or interior
> - ***External:*** Outer or exterior
> - ***Rostral:*** Towards the head. This is used more in embryological and zoological studies; 'rostre' means the beak or the pout and rostral is towards the beak or pout of the animal. In human beings this is taken as 'nearer to the anterior part of the head' and is usually employed in descriptions of brain; an example would be, 'the frontal lobe of cerebrum is rostral to the occipital lobe'.

Terms of Laterality

These are terms which indicate the left or right sides or both.

- ***Unilateral:*** Only one side. Structures which occur only on one side of the body are unilateral. An example is the spleen that occurs on the left side of the body
- ***Bilateral:*** Both sides of the body. Structures which have both right and left members are bilateral. Example is the kidney
- ***Ipsilateral:*** Same side of the body. Right hand and right foot are ipsilateral
- ***Contralateral:*** Opposite side of the body. Right hand and left foot are contralateral.

Terms of Size and Shape

While describing structures, it is essential to compare their sizes and even shapes. Thus terms which specifically talk about sizes and shapes of structures are also frequently used.

- ***Great/magnus:*** Indicating larger size/longer length/bigger appearance
- ***Small/parvus:*** Indicating smaller size/shorter length/smaller appearance
- ***Greater/major:*** Indicating larger size but used in comparison of two identical or related structures
- ***Lesser/minor:*** Indicating smaller size but used in comparison of two identical or related structures.

When the term 'magnus' is used, there need not essentially be another structure befitting the 'parvus' description. But, when the term 'major' is used, there is usually another related structure that befits the 'minor' description.

Terms of Movements (Figs 1.9 and 1.10)

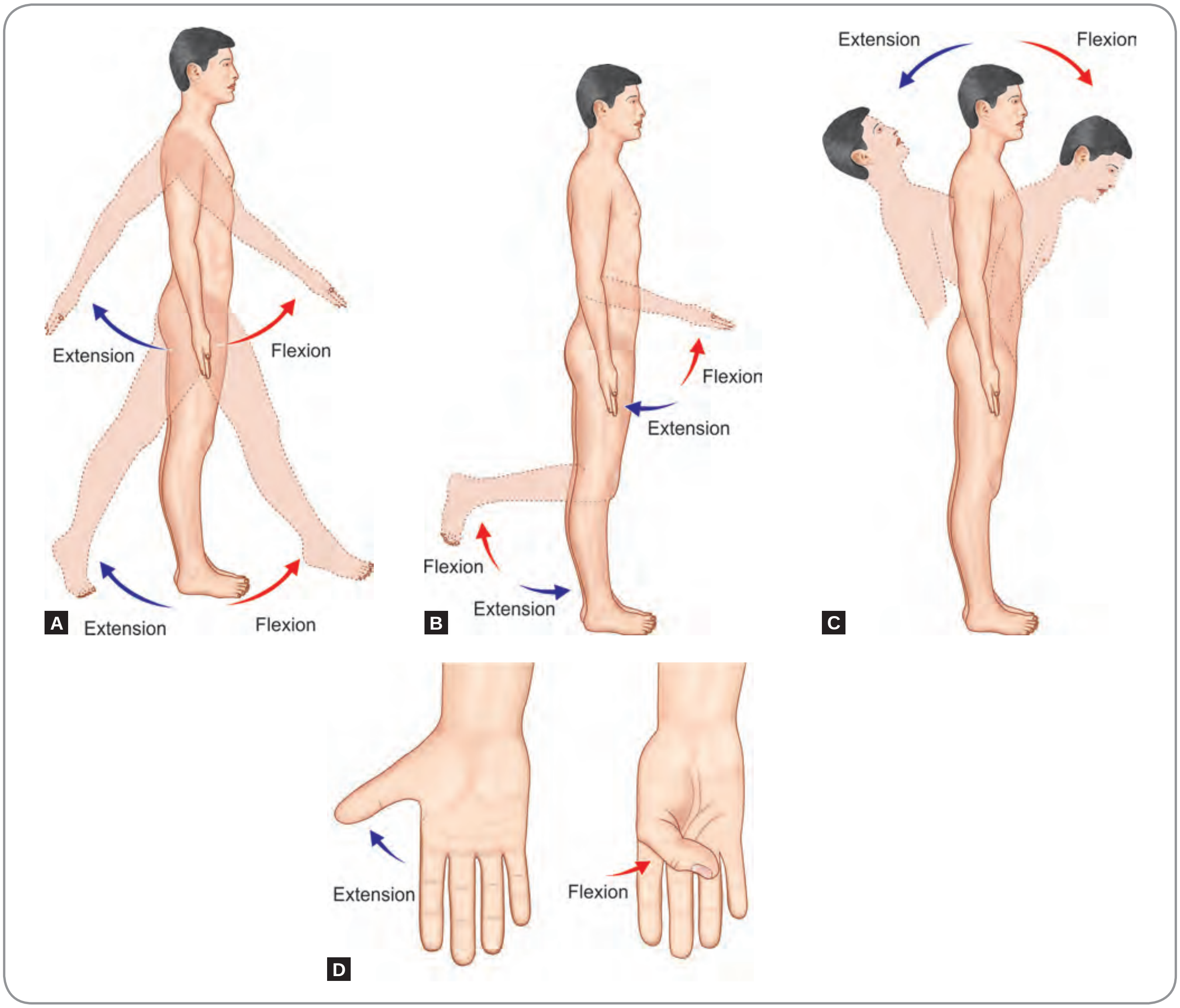
The human body is a jointed structure and movements can be seen to occur at these joints. Various movements have been given separate names.

- ***Flexion–extension:*** To flex is to bend or make an angle; flexion is thus bending. To extend is to stretch or straighten; extension is straightening from the flexed position. Flexion usually brings two anterior (or ventral) surfaces closer to one another; extension is back to normal from flexed position (Figs 1.9A to D).
- ***Abduction–adduction:*** To abduct is to take away or lead away (ab=from, duco=lead); abduction is therefore draw away from median plane or midline. To adduct is to bring closer (ad=to, duco=lead); adduction is drawing closer to the median plane or midline (Figs 1.10A and B).
- ***Medial rotation-lateral rotation:*** Medial (internal) rotation is turning inwards and lateral (external) rotation is turning outwards (Fig. 1.10D).

Movements occur around axes. As for any three dimensional structure, three perpendicular axes can be defined for the human body too. These are the transverse axis, the ***longitudinal axis*** and the ***antero-posterior axis***. Flexion-extension movements occur around the transverse axis and in the sagittal plane. A typical example can be seen in the elbow joint; when the anterior aspects of the upper arm and the forearm come close to each other, it is ***flexion***; when the anterior aspects move away and the limb straightens out, it is ***extension***. Abduction-adduction movements occur around the antero-posterior axis. Example of this can be seen in the shoulder joint; when the limb is lifted and drawn away from the trunk, it is ***abduction***; when the limb is brought back to hang by the side of the trunk, it is ***adduction***.

> With regard to the fingers and toes, the terms 'abduction' and 'adduction' have to be used in proper understanding. The axial line of the upper limb passes through the middle of the upper arm, forearm and wrist. It continues down the middle of the hand and runs through the middle finger. Hence, abduction and adduction of fingers are described with reference to this line of axis. In abduction, all fingers move away from the middle finger; to effect this, the thumb and the forefinger move laterally while the ring and the little fingers move medially. The middle finger has no adduction since it lies in the axial line; but

contd...



Figs 1.9A to D: Scheme to explain flexion and extension at different parts of the body

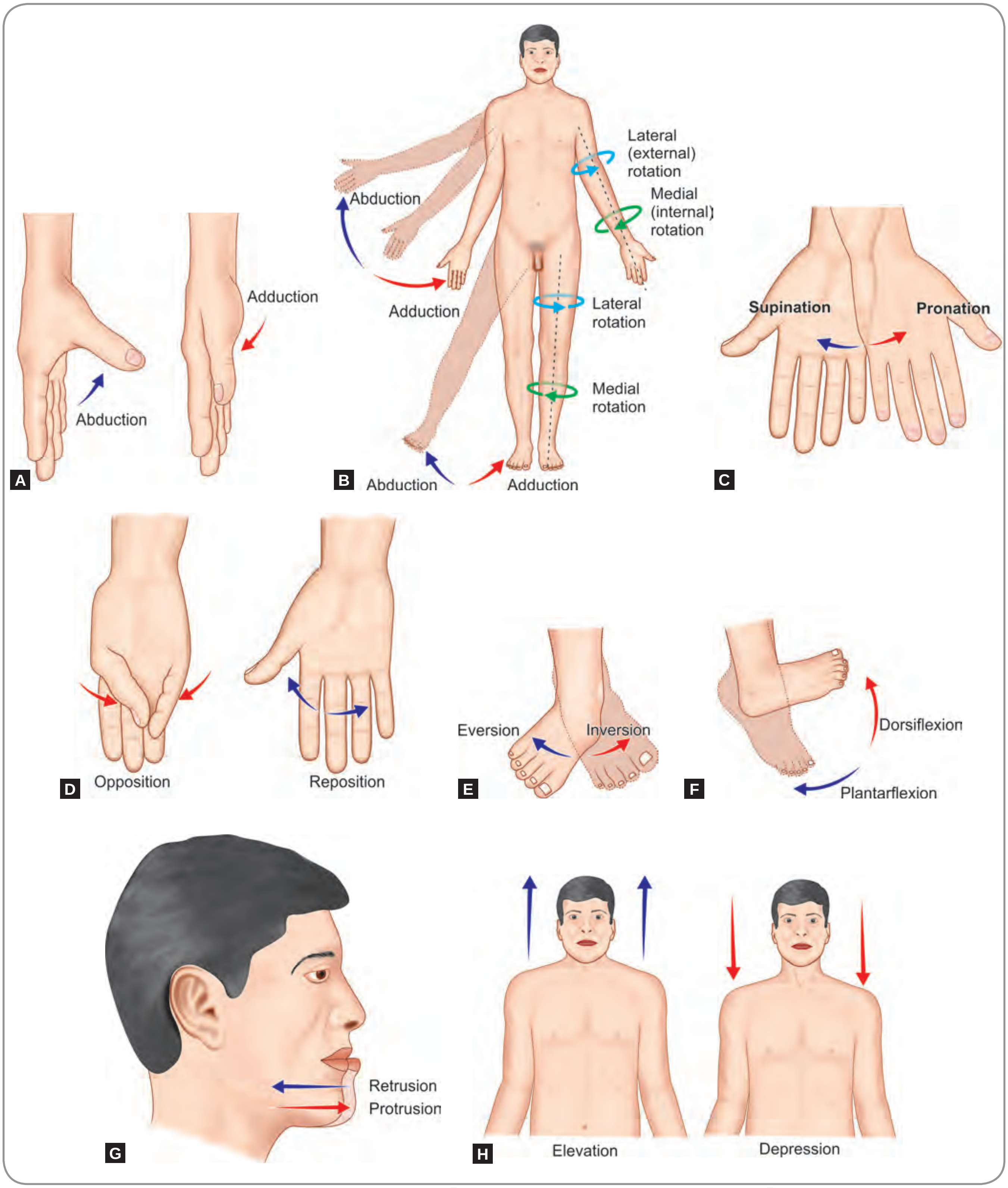
contd...

it has two abductions – one moving it medially and the other moving it laterally; these two movements are called medial abduction and lateral abduction. In the lower limb, the axial line passes through the middle of the thigh, leg and ankle. However, it continues down the foot and the second toe. Thus, abduction and adduction movements of the toes will be described with reference to this line.

Rotational movements occur around the longitudinal axis. Example is the upper limb rotating at the shoulder joint. During medial rotation, the anterior surface turns inwards and the lateral (radial) border turns to face forwards; during lateral rotation, the posterior surface turns inwards and the lateral border turns to face backwards.

When extension proceeds beyond straightening, there is an attempt of posterior or dorsal aspects coming into contact; this is called ***hyperextension***. It can well be seen in the wrist. Bending the wrist in such a way to bring the palm closer to the anterior aspect of forearm is flexion. Taking the hand back to its normal position is extension. If the wrist is further extended in an attempt to bring the dorsum of hand closer to the posterior aspect of forearm, it is hyperextension.

Circumduction (circum=around) is a combination of all movements but in sequence. Flexion, abduction, extension and adduction occur in sequence; a cone is thus described. Rotational movements accompany the other movements and therefore all the axes are involved.



Figs 1.10A to H: Terms of movement **A.** Abduction-adduction **B.** Medial rotation-lateral rotation **C.** Pronation-supination **D.** Opposition-reposition **E.** Eversion and invasion **F.** Dorsiflexiion-plantarflexion **G.** Retrusion-protrusion **H.** Elevation-depression

Special Terms of Movements

Certain special terms are used to describe special movements.

Pronation-supination is one such set (Fig. 1.10C). To ***pronate*** is to flex. This term was originally applied to indicate bending of the entire body forwards, when the individual is facing downwards or is prone. The terms ***prone*** and ***supine*** are still used with reference to the position of the entire body. As already seen, supine is lying on the back and prone is lying face down. However, the terms ***'pronation'*** and ***'supination'*** are being used in relation to the forearm. To pronate the forearm is to turn it in such a way that the palm faces downwards when the forearm is resting on a table or on the lap. This, if in normal anatomical position, will mean palm facing backwards. Supination is when the palm is facing upwards while the forearm rests on the table. This is equivalent to the limb hanging by the side of the trunk with the palm facing forwards.

Abduction-adduction movements occur at the wrist. The hand is angulated in relation to the forearm; abduction which carries the hand towards the radial side (the angle between the thumb and forearm becomes less than 180 degrees) is otherwise called radial deviation; adduction which carries the hand towards the ulnar side (the angle between the little finger and the forearm is less than 180 degrees) is called ***ulnar deviation***.

The thumb has a movement that goes by a different name. It is possible to touch the tip of the thumb to the tips of the other fingers. This movement is called ***opposition*** (Fig. 1.10D). Pinching and lifting a teacup by its handle are movements when opposition comes into play. Movement of thumb back to anatomical position from opposition is ***reposition***.

In the lower limb, the foot is capable of going through another set of movements. These are the ***inversion-eversion*** movements. When the lateral border of the foot is placed on the ground and the medial border raised, the sole faces inwards; this is ***inversion***. When the opposite occurs, that is, when the medial border placed on the ground and the lateral border raised, the sole faces outwards; this is ***eversion*** (Fig 1.10E).

The movement at the ankle which causes the dorsum of the foot to come closer to the leg is actually extension and is frequently referred to as ***dorsiflexion***. The opposite movement where the dorsum moves away from the leg is the ***plantarflexion*** (Fig. 1.10F).

Protraction–retraction are terms used with reference to the lower jaw. To protract (pro=forwards, traho=pull) is to move forwards; protraction of the lower jaw is pushing of the jaw forwards in relation to the upper jaw and rest of the face. To retract is to move backwards. Retraction of the lower jaw is drawing it back. ***Protrusion*** and ***retrusion*** are terms which can be substituted for protraction and retraction respectively (Fig. 1.10G).

Elevation raises a part or structure and ***depression*** brings it down (Fig. 1.10H).

Dissection

Learn the following terms and their meanings:

- ***Dissection/dissect:*** To open or expose a region of the body and the structures contained therein.
- ***Blunt dissection:*** To separate various structures (in a region) with fingers or a blunt probe (like the handle of scalpel or the back of forceps); this is the most preferred technique in most situations.
- ***Sharp dissection:*** Dissection done with a sharp scalpel; usually discourages and used rarely by well trained anatomists.
- ***Cleaning up/clean a muscle:*** To remove fat and strands of connective tissue on the surface and border of a muscle in such a way that the fascicles are clearly made out; the borders of the muscle should be cleared from surrounding structures.
- ***Cleaning a nerve or vessel:*** To remove connective tissue over the nerve or vessel so that the nerve or vessel is clearly visible along with its branches.
- ***Define a structure:*** To clean the structure in such a way that its relationships are well seen and its presence are well marked using only blunt dissection.
- ***Reflect (skin or fascia):*** To fold back the free edge of the skin or fascial flap, so as to view the underlying structures.
- ***Retract:*** To pull/push a structure to one side so as to clearly view underlying structures; this is a temporary measure and the retracted structure should be placed back in position; no damage should be caused to the structure because of retraction.
- ***Transect:*** To cut a structure transversely into two.

Note: It is necessary to remember that no structure should be cut away or removed (except some fascia and fat) unless specifically instructed. Skin and fascial flaps reflected during study should be placed back.

Other Subdivisions of Anatomy

Apart from the subdivisions of Anatomy mentioned above (and which a medical student would frequently encounter), there are also other subdivisions The knowledge of Anatomy is necessary for several areas of work and at various levels of importance. Thus use of anatomical knowledge when and where required has given rise to various other subdivisions which a medical professional may or may not have an opportunity to come across.

- ***Surgical anatomy:*** Study of structures with emphasis on direct, practical significance in surgical practice;
- ***Relief anatomy:*** Study of the various areas and structures in relation to the external features and relief of the body (outline appearance of the body);
- ***Sports anatomy:*** Study of the effects of various sports on the structures of the body;
- ***Anatomical anthropology:*** Study of anatomy of human with differing traits (due to race, bodily constitution, habitat);
- ***Dynamic anatomy:*** Study of the structure and function of the locomotor apparatus and supportive organs of locomotion (this has extensive importance in sports and physical culture);

- ***Plastic anatomy:*** Study of the external form and proportions of the body as required for artists and sculptors;
- ***Morbid anatomy or pathological anatomy:*** Study of structures in a sick individual and the morbid changes in such organs;
- ***Age anatomy:*** Study of the effects of ageing on various structures of the body;
- ***Gerontic anatomy:*** Study of structures in relation to the degenerative changes due to old age; this is similar to age anatomy, but relates to old age and not to anatomical changes until the fourth or fifth decade of life (Greek.geron/gerontos=old man);
- ***Phylogeny:*** Study of the human individual and his/her development in relation to the developmental processes of lower life forms (Greek.phylon=genus; genesis=development);
- ***Ontogeny:*** Study of the development of the individual throughout life(Greek.onthos=being);
- ***Teratology:*** Study of malformations (Greek.teras/teratos=monster; logos=study/science).

Added Information

- Anatomy, is generally thought to be merely descriptive; i.e plainly describing how the body or parts of body are built However, description is a means rather than an end. Anatomy attempts to explain not only how the body is built but also why it is made so. This is done by studying the external and internal relationships of the various structures and analysing as to why a particular structure is present in a particular position/location and in a particular pattern/way.
- '*Anatomy, in union with Physiology, rules the world of Medicine as an empress*' – AP Valter, a 19th century anatomist.
- Anatomical terms are actually anatomicomedical terms; they are standardised in the international reference guide called the International Anatomical Terminology. Terminologia Anatomica is the collection of anatomical terms and Terminologia embryologica, the collection of embryological terms. Both these give the terms in Latin and in English(which are the official versions). However, for several structures there are also other names which are regularly used, e.g., pharyngotympanic tube is the official name; whereas auditory tube is a commonly used name.
- Eponyms and names which incorporate names of people, e.g., the inguinal ligament is the Poupart's ligament; subsartorial canal is the Hunterian canal. Though eponyms are generally discouraged during study of Anatomy, they are frequently used in clinical settings.
- Flexion-extension movements occur around the transverse axis, the terms may sometimes be used differently. When the entire body is bent forwards, it is flexion or forward flexion; the axis of movement, here, is transverse. When the body is bent sideways, it is lateral flexion; the axis, in such case, is anteroposterior. Further definition is added by additional description like left lateral flexion (bending to the left) or right lateral flexion (bending to the right). When the neck is bent sidewards, the same term 'lateral flexion' is used.

STRUCTURES CONSTITUTING THE HUMAN BODY

While describing the various structures of the human body, it is essential to understand that most human beings have the same pattern of structures. This pattern can be called the ***norm*** or the commonest anatomy seen in most individuals.

In a few individuals, alterations/modifications to the commonest can be seen. These are described as ***variations*** or ***anomalies*** (Greek.anomalos=irregular). ***The basic difference between a variation and an anomaly is that, a variation does not disturb the function but an anomaly usually produces some compromise of the function***.

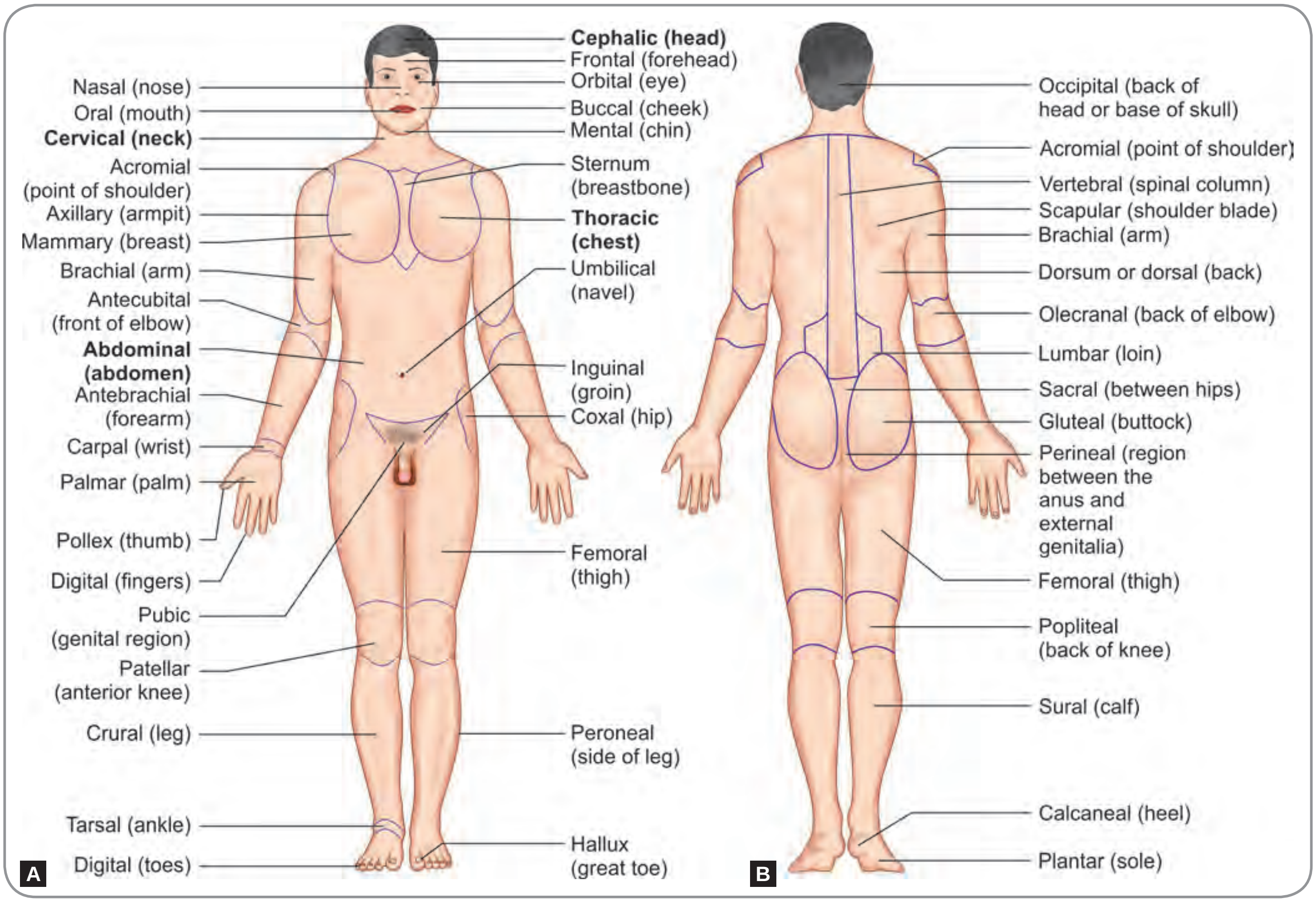
Main Subdivisions of the Human Body (Fig. 1.11)

For convenience of description the human body is divided into a number of major parts. These parts have specific anatomical names and it can be seen that these names (and/or terms) are repeatedly used during the study of human body. These names have also been used in describing various structures related to the concerned body parts, either in complete form or in part.

The uppermost part of the body is the ***head (caput)***. The ***face (facies)*** is part of the head. Below the head, is the ***neck (collum)***. In the head, the following areas can be identified: ***forehead (frons), highest point (vertex), back of head (occiput)*** and ***temples (tempora***). Below the neck, is the region called the ***chest***. In anatomical terminology the chest is referred to as the ***thorax***. The thorax is in the form of a bony cage within which the heart and lungs lie. Below the thorax, is the region commonly referred to as 'stomach' or 'belly'. The correct name is ***abdomen***. The abdomen contains several organs of vital importance to the body. Traced downwards, the abdomen extends to the hips. That part of the abdomen present in the region of the hips is called the ***pelvis***. The thorax and the abdomen together form the ***trunk (truncus)***. Back (dorsum) is that part of the trunk which is the posterior aspect of both the thorax and the abdomen. The lowest part of the trunk around the urinary, reproductive and anal openings is the ***perineum.***

Attached to the trunk, there are the ***upper*** and ***lower limbs***, or the upper and lower ***extremities***. The upper limb is divided into the ***arm (brachium)***, the ***forearm (antebrachium***) and the ***hand (manus***). The lower limb is divided into the ***thigh (femoral***), the ***leg (crus***) and the ***foot (pes***).

Taking the whole body into account, we can say that the body is made of the axial and the appendicular regions. The axial region is the one that makes up the main axis of the body and consists of the head, neck and trunk. The appendicular region (appendix or appendage= something that is added) consists of the limbs.



Figs 1.11A and B: Parts of human body **A.** Anterior view **B.** Posterior view

Structural Components

The human body has several different kinds of structures.

Their physical characteristics are also different. How then can these be named? Certain general terms are used to denote certain parts or structures or the whole of structures:

- ***Organism:*** The living being that is capable of growing and multiplying; it is also capable of exchanging substances with its environment;
- ***Tissue:*** A group of similar cells which have specific morphological and biochemical properties; sometimes, it can have cells of other types to give support or additional advantage;
- ***Organ (Greek.organon-tool):*** A part of the body that serves as an instrument for adaptation of the individual/organism with the environment; the organ is an integral part of the whole and has its own structure, function, position and development; it cannot exist separately outside the individual/organism;
- ***Permanent/definitive organs:*** Those characteristic of the adult anatomy and persist throughout life;
- ***Temporary/provisional organs:*** Those which appear in a particular stage of development and then disappear;
- ***Morpho-functional organs:*** Those which themselves are made up of many structures and tissues but form part of some other larger organs; example of this is a nephron which by itself is a part of the kidney;
- ***System of organs/organ system:*** The collection of homogenous organs marked by a common structure, function and development; it can be defined as a morphological and functional assemblage of organs; examples are bone system, muscular system and digestive system;
- ***Apparatus:*** The collection of heterogenous organs which are united for the performance of a common function; example is the endocrine apparatus, where endocrine glands with different structural and developmental properties are clubbed because of a common function, namely, production of hormones; the term ***apparatus*** is also used sometimes to denote smaller parts/structures of an organ marked by a definitive functional importance; example of such usage can be seen in phrases like ***the receptor apparatus of the kidney***, ***the receiving apparatus of the neuron*** etc;
- ***Super system:*** The functional togetherness of two or more organ systems for the sake of bringing about

certain functions; example is the locomotor system; though called a ***system***, it actually is a ***supersystem*** because the muscular system, the skeletal system and some parts of the nervous system together constitute the ***locomotor system*** and this togetherness is essentially for locomotor functions.

As we study various parts of the body, we notice that several different kinds of structures are present in a given organ or region or part. These structures have different physical and functional qualities.

The basic framework of the body is provided by a large number of ***bones*** that collectively form the ***skeleton***. As bones are hard they not only maintain their own shape, but also provides shape to the part of the body within which they lie.

In some situations (e.g., the nose or the ear) part of the skeleton is made up, not of bone but of, a firm but flexible tissue called ***cartilage***.

Bones meet each other at ***joints***, many of which allow movements to be performed. At joints, bones are usually united to each other by fibrous bands called ***ligaments***.

Overlying (and usually attached to) the bones are the ***muscles***. Muscles are what the layman refers to as flesh. In the limbs, muscles form the main bulk. Muscle tissue has the property of being able to shorten in length. In other words muscles can contract, and by contraction they provide power for movements. A typical muscle has two ends, one (traditionally) called the ***origin***, and the other called the ***insertion***. Both ends are attached, usually, to bones. The attachment of a muscle to bone may be a direct one, but quite often the muscle fibres end in a cord like structure called ***tendon. Tendons*** convey the pull of the muscles to the concerned bones and are very strong structures. Sometimes a muscle may end in a flat fibrous membrane. Such a membrane is called an ***aponeurosis***.

When we study a limb, we find that the muscles within it are separated from skin, and from each other, by a tissue in which fibres are prominent. Such tissue is referred as ***fascia***. Immediately beneath the skin the fibres of the fascia are arranged loosely and this loose tissue is called ***superficial fascia***. Over some parts of the body the superficial fascia may contain considerable amounts of fat. Deep to the superficial fascia the muscles are covered by a much better formed and stronger membrane. This membrane is the ***deep fascia***. In the limbs, and in the neck, the deep fascia encloses deeper structures like a tight sleeve. The major difference between the superficial fascia and the deep fascia is that the latter has closely packed fibres and appears sheet like.

Membranes similar to deep fascia may also intervene between adjacent muscles forming ***intermuscular septa***. Such septa often give attachment to muscle fibres.

Running through the intervals between muscles (usually in relation to fascial septa) are the ***blood vessels***, ***lymphatic vessels***, and ***nerves***. Blood vessels are tubular structures through which blood circulates. The vessels that carry blood from the heart to various tissues are called ***arteries***. Those vessels that return this blood to the heart are called ***veins***. Within tissues, arteries and veins are connected by plexuses of microscopic vessels called ***capillaries***.

Lymphatic vessels are delicate, thin walled tubes. They are difficult to be seen by naked eye. They often run alongside veins. Along the course of these lymphatic vessels small bean-shaped structures are present in certain situations. These are the ***lymph nodes***. Lymphatic vessels and lymph nodes are part of a system that plays a prominent role in protecting the body.

Running through tissues, often in the company of blood vessels, are also solid cord like structures called ***nerves***. Each nerve is a bundle of a large number of ***nerve fibres***. Each nerve fibre is a process arising from a ***nerve cell*** (or ***neuron***). Most nerve cells are located in the brain and in the spinal cord. Nerves transmit impulses from the brain and spinal cord to various parts and tissues of the body. They also carry information from the parts and tissues to the brain. Impulses passing through nerves are responsible for contraction of various muscles and for secretions by various glands. Sensations like touch, pain, sight and hearing are all dependent on nerve impulses travelling through the nerve fibres.

Bones, muscles, blood vessels are seen in all parts of the body. In addition to these, ***organs*** are seen in some parts of the body. Organs are otherwise called ***viscera*** (Singular.viscus; plural.viscera; Latin.visko=soft; other name: splanchna) and are usually seen in the cavities of thorax and abdomen Some of the viscera are solid (e.g., the liver or the kidney), while others are tubular (e.g., the intestines) or sac like (e.g., the stomach). The viscera are grouped together in accordance with their functions to form various organ systems. Some examples of organ systems are the ***respiratory system*** responsible for providing the body with oxygen, the ***alimentary*** or ***digestive system*** responsible for the digestion and absorption of food, the ***urinary system*** responsible for removal of waste products from the body through urine and the ***genital system*** which contains organs concerned with reproduction.

Multiple Choice Questions

1. Study of internal structures using CT scans and MRI images is:
   a. Internal anatomy
   b. Applied anatomy
   c. Imaging anatomy
   d. Experimental anatomy
2. The term to indicate a structure closer to root is:
   a. Distal
   b. Proximal
   c. Cephalic
   d. Rostral
3. All of the following are terms of movement except:
   a. Contralateral
   b. Abduction
   c. Hyperextension
   d. Circumduction
4. Pronation of the forearm makes the palm:
   a. Face upwards
   b. Face backwards
   c. Move medially
   d. Spread the fingers
5. Structures which convey the pull of a muscle to the attached bone are:
   a. Nerves
   b. Tendons
   c. Ligaments
   d. Tendon sheaths

ANSWERS

1. c **2.** b **3.** a **4.** b **5.** b

Chapter 2

Body Plan, Skin and Fasciae

Frequently Asked Questions

- What are the functions of skin?
- Briefly describe superficial and deep fasciae of the body.
- What is an eponychium?
- Where are the sebaceous glands found and what is the function of sebum?
- How does melanin prevent skin cancer?
- Describe the structure of skin.

HUMAN BODY PLAN

The structures, their organisation and features follow a typical plan. It is easy to understand the details of the structures if this basic plan is first thought of.

- ***System of concentric tubes:*** This can be also described as the tube-within-tube plan. A smaller tube is present within a larger tube. The entire axial region of the body forms the larger tube within which is found the thinner and smaller tube of digestive system.
- ***Bilateral symmetry:*** The right and the left halves of the body tend to have similar structures and appearances. Many of the structures occur in pairs Examples are the right and left lungs. Structures in the midline are unpaired but have identical right and left halves. Examples are the nose, the sternum and the urinary bladder. All these have identical right and left sides. However, due to functional requirements, all structures cannot confirm to this kind of symmetry and there are structures which specifically occur on one side of the body. Examples are the heart and the liver; the heart is placed more to the left and the liver is on the right side.

If the side of such a structure is altered, it is then an ***anomalous*** condition.

The external appearance of the human body does have a bilateral symmetry.

- ***Axial vertebral column:*** A bony string called the vertebral column is present on the posterior or dorsal aspect of the body. It is made up of individual pieces of bone called the ***vertebrae*** (singular, vertebra) and is usually called the ***backbone***
- ***Segmentation of the body:*** Segments are the units of similar structure and function; these are placed one after the other or one below the other from head to the lower aspect of trunk. In humans, the outer tube of the body shows this pattern of segmentation. The bony vertebral column and the spinal cord also show evidences of such segmental pattern.
- ***Dorsal nerve cord:*** The nervous system is based on the presence of a dorsally placed nerve cord. The brain and the spinal cord represent this pattern.
- ***Gills and pharyngeal pouches:*** In fishes, the gills have clefts between them. In humans, these clefts form the pharyngeal pouches during development and subsequently several structures are derived from these pouches.

Once the outline of the general plan is understood, various structures can now be studied.

SKIN (FIG. 2.1)

Skin, body s largest and the most extensive sensory organ, forms the outer and protective covering of the body. The skin covers the entire body; makes up about 7% of the body weight; varies in thickness in different parts of the body. It is usually subdivided into a superficial cellular part called the ***epidermis*** and the deep connective tissue part called the ***dermis***.

Epidermis

The ***epidermis*** is extremely thick on the palmar aspects of the hands and the plantar aspects of the feet, in order to withstand the constant wear and tear that occurs in these

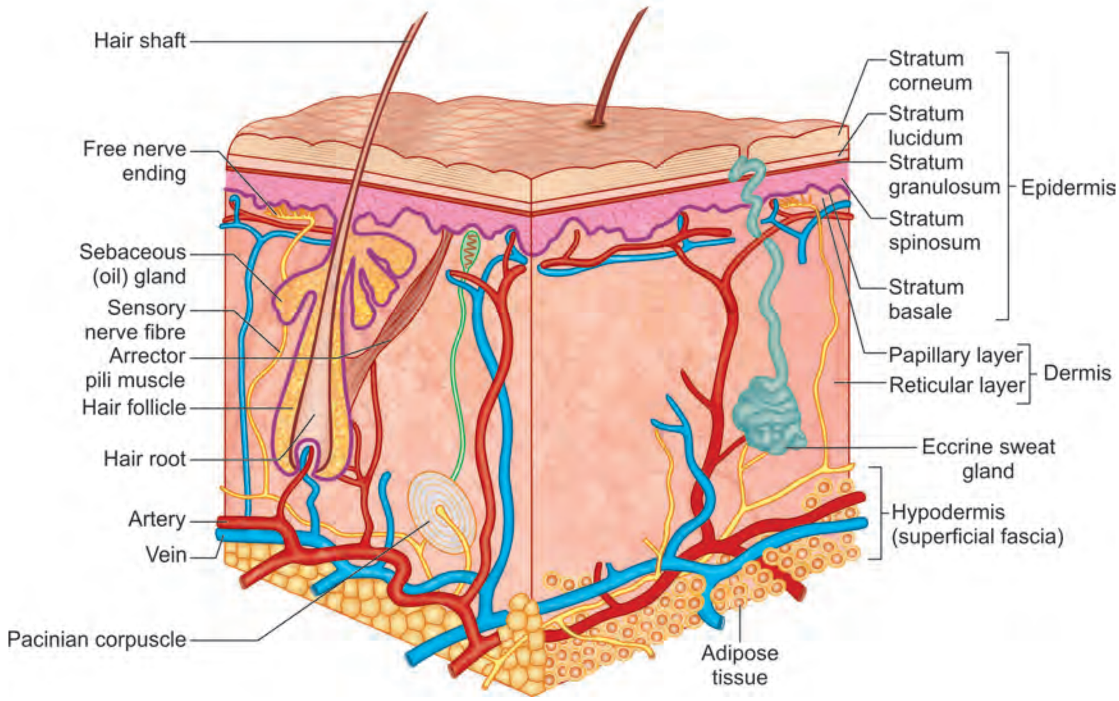


Fig. 2.1: Structure of skin

regions. In other areas of the body, it is thin; examples are the anterior surfaces of the arm and the forearm. The epidermis is avascular.

Dermis

The dermis which is composed of connective tissue has blood vessels, lymphatics and nerves. It is of varying thickness in different parts of the body; in general it is thinner on the anterior than on the posterior surface; it is thinner in women than in men. The dermis is connected to the underlying deep fascia or to the bones by the superficial fascia. Because the latter is immediately underneath the skin, it is also called the subcutaneous tissue (cutis-skin, sub-below or beneath).

The dermis has densely packed collagen, elastic and reticular fibres. These fibres are responsible for the tone of the skin and provide strength, toughness, resilience and recoil. Though the fibres run in various directions, in a specific location, they run parallel to each other. The pattern of the fibres determines the wrinkle lines of the body.

Specialised Structures of Skin

The skin also contains specialised structures and gives rise to its appendages. Together with its specialised structures, the appendages and the subcutaneous tissue immediately underneath, it forms the ***integumentary system*** (Latin. integumentare=covering).

The specialised structures occur within the dermis and are the hair follicles, the sebaceous glands and the sweat glands.

Projections of epidermis into the dermis form the hair follicles; they lie oblique (slanting) to the skin surface; the inner end of the hair follicle where it penetrates deep into the dermis, is expanded and is called a ***hair bulb*** (Fig. 2.2). The hair bulb is concave at its end and the concavity is occupied by a mass of connective tissue with blood vessels in it. The connective tissue mass appears like a small finger projecting into the hair bulb and hence, is called the ***hair papilla***. Each hair bulb is surrounded on its external aspect by a network of sensory nerve fibres called the ***root hair plexus*** When the hair is bent or moved, these nerve endings are stimulated. Hairs, therefore, act as touch receptors; one experiences the tickling sensation when the hairs are continually stimulated. The hair runs up from the hair bulb through the neck of the follicle (the slightly constricted part of the follicle near the epidermis) and the epidermis to the external aspect of the skin Because of the slanting nature of the hair follicle, the hair as it emerges out on the surface, is also slanting.

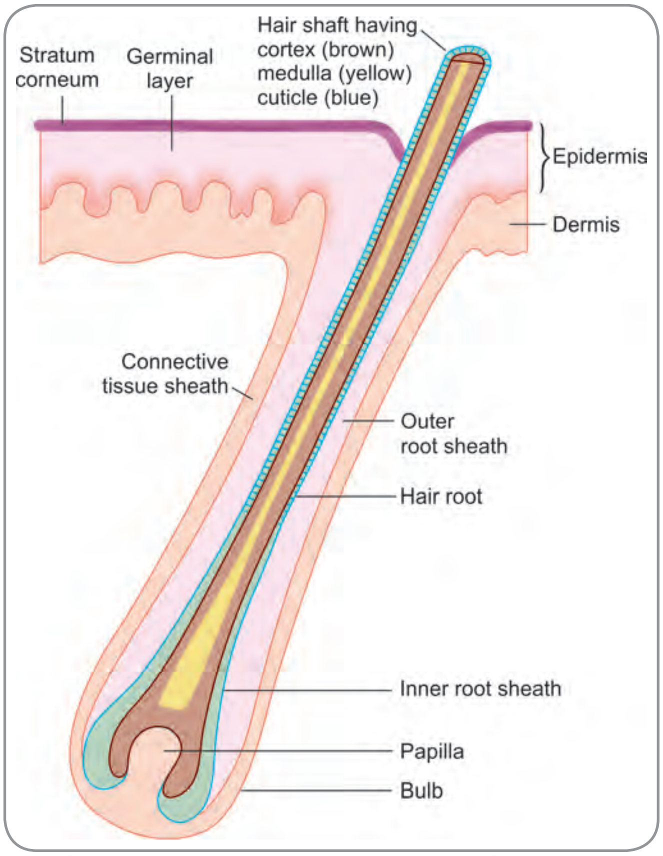


Fig. 2.2: Scheme to show some details of a hair follicle

Dissection

Skin incision is the first step in dissection. Before making an incision, mark it on the surface of the cadaver with wet chalk piece.

Incision should be made in a smooth straight stroke with a sharp scalpel. The edges of the incision should not be serrated or lacerated. If the incised skin is kept back in its original position, no internal structure should be visible and the skin should close normally.

The thickness of skin varies from region to region and from part to part The incision should go through the entire thickness of the skin. To know the nature of skin of the region you need to dissect before making the incision.

Once the incision is made, hold a small tip of skin with a toothed forceps and start reflecting. Reflection is made easier by: (a) hydrating the area–apply cotton soaked in water or gently spray water and (b) separating the skin layer from the underlying tissue with the back of the scalpel. As you insinuate the back of the scalpel between the two layers more and more with your right hand, exert a gentle pull on the skin bit you are holding on your left; skin can thus be reflected easily, methodically and without any damage.

Nerves and vessels which enter into the deeper aspect of the skin should be carefully cleaned and preserved.

Reverse dissection: This is the method used to naturally separate structures from each other. It can be used even for skin reflection. The scissor blades are kept closed and the scissors is slowly entered into the area to be dissected or cleaned. Gradually and slowly, the blades are opened; this sp ays the tissue apart. Planes between var ous fascial layers can be approached by this method.

- A ***hair*** is a long and flexible strand projecting from the hair follicle. It is made up of keratinised cells and has a shaft (the part that projects above the skin surface) and a root (the part that is embedded in the skin).
- ***Sebaceous glands:*** (Greek.Sebashus=greasy) they are present on the slanting undersurface of the follicle and lie within the dermis. They open near the neck of the follicle and pour out their secretion, the sebum. Sebum is oily and passes along the hair to reach the skin surface. It helps to preserve the flexibility of the hair and also lubricates the skin surface. It collects dirt and dust and has been found to have bactericidal (bacteria killing) action.
- ***Arrectores pilorum:*** The muscle (or the arrector pili, Greek.Arrector=raiser, pilore=hair) runs from the undersurface of the follicle to the superficial aspect of dermis. Its contraction causes the hair to become more vertical and the sebaceous glands to get compressed, thus pouring out more sebum.
- ***Sweat glands:*** The long tubes with highly coiled ends which usually lie in the superficial fascia. Thus, these glands extend through the full thickness of the dermis. They are present all over the body except on the nipples and some parts of external genitalia. Sweat produced by the sweat glands is poured on the skin surface; evaporation of sweat, causes the skin to cool. On an average, a human being produces 500 ml of sweat per day; however, this amount can increase to about

Histology of Skin (Fig. 2.3)

The epidermis has several layers called ***strata*** (singular. stratum;) and four types of cells namely, the keratinocytes, melanocytes, Merkel cells and Langerhan cells. Wherever skin is thick, the epidermal strata are five; in thin skin they are four. From deep to superficial, these are stratum basale, stratum spinosum, stratum granulosum, stratum lucidum and stratum corneum.

- ***Stratum basale (basal layer):*** Single row of cells, predominantly stem cells representing young keratinocytes along with some merkel cells and melanocytes; rapid and extensive mitosis occurs here;
- ***Stratum spinosum (spiny layer):*** Many rows of cells, mostly keratinocytes with some langerhan cells; mitosis occurs here but less rapidly; tonofilaments containing pre-keratin (a tension resisting protein) are present in this layer;
- ***Stratum granulosum (granule layer):*** 3 to 5 rows of keratinocytes; abundant tonofilaments; keratinocytes secrete water proof glycolipid that slows down water evaporation across epidermis;
- ***Stratum lucidum (clear layer):*** Occurs only in thick skin; few rows of dead kerat nocytes;
- ***Stratum corneum (horny layer):*** Most external part of skin; many rows thick; cornified or horny cells which are filled completely with keratin; layer that protects skin from abrasion and penetration and also gives water proofing

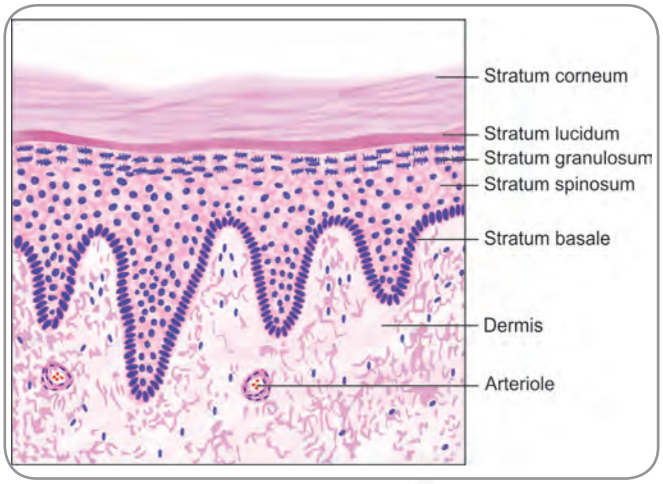


Fig. 2.3: Section showing the layers of epidermis

12 litres depending upon the climate around and also upon exercise done by an individual.

- ***The appendages or the derivatives of skin*** are the nails, the mammary glands, the ceruminous glands and the teeth enamel
- ***Nail:*** On the dorsal surfaces of the tips of fingers and toes, keratin plates occur over the epidermis. Each nail (also called the nail plate) (Fig. 2.4A) has a distal free edge, a body (the visibly seen attached part) and a root. The proximal edge of the nail plate which is embedded in skin is the root. Except for the projecting distal edge, the other sides of a nail are overlapped by skin folds called nail folds. The nail fold on the proximal aspect projects a little over the nail body and is called the ***eponychium*** (Greek. epo=over, nikeum=nail). The skin surface underneath a nail is the nail bed. The nail plate itself corresponds to the superficial keratinised layers of epidermis and the nail bed to the deeper layers of epidermis Underneath the nail bed is the dermis that has a rich network of blood capillaries. Due to this, the nail appears pink in colour (Fig. 2.4B).
- ***Ceruminous glands*** are modified sweat glands in the external ear. They are responsible for the formation of ear wax Mammary glands are modified sweat glands, thus modified to secrete milk.

Skin has several important functions. These are as follows:

- Giving protection from environment, from ultraviolet radiation, from injuries and from harmful substances,
- Acting as a container for the internal structures and organs of the body,
- Regulating body temperature (or thermoregulation) through evaporation of sweat and through its blood vessels
- Preventing dehydration,
- Providing sensations through the superficial nerves and their endings,
- Synthesising and storing vitamin D.

FASCIAE

Fasciae (singular, fascia) can be defined as the wrapping and packing material of the body. Various fasciae surround

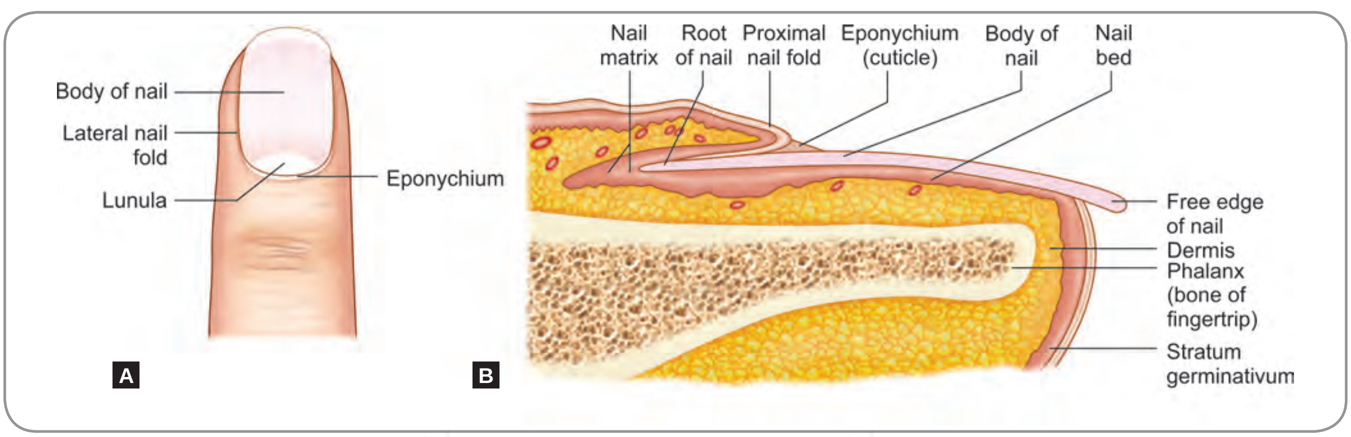
Dissection

When you make the necessary incision in an area and then reflect the skin, the whitish strands which you see constitute the superficial fascia. It is better to reflect the superficial fascia along with the skin by a blunt dissection. By this method, the blood vessels and nerves which enter the superficial fascia and skin from the deep fascia can be found easily and prevented from damage.

You will find fat in the superficial fascia. It can be seen as yellowish brown globules which are shiny and slippery. In areas where fat is more, nerves and vessels should be carefully traced; otherwise, the latter may be inadvertently cut

As the skin-fascia flap is lifted and turned, cutaneous nerves can be seen. They are normally accompanied by tiny arteries and minute veins. Larger veins can also be seen in the superficial fascia, especially in the limbs. These are usually single and run for some distance before piercing the deep fascia to drain into a deep vein.

Deep fascia, in most parts of the body, can be seen as a sheet of white glistening fascia.



Figs 2 4A and B: Nail **A.** Parts of the nail **B.** Longitudinal section

structures and tissues, form packing blocks between structures thus keeping them in position and also provide insulation in many places.

Superficial Fascia

The ***superficial fascia*** immediately beneath the skin is also called the ***subcutaneous layer*** (Latin.Sub=below, cutis=skin) or the ***hypodermis*** (Fig. 2.1) (Greek. Hypo=below, dermae=skin). It has areolar and adipose connective tissue The hypodermis fixes the skin to the underlying structures and allows it to slide over. This sliding mechanism gives protection to the skin The skin is able to slide and move away from many of the blows, hits and rubs which most of us encounter in our daily lives. Storage of fat can happen in the adipose and areolar tissue. The superficial fascia, because of the fat deposits, acts as an insulator and prevents heat loss from the body.

Deep Fascia

Underlying the superficial fascia is the ***deep fascia***. It is made up of dense connective tissue and has no fat. Its thickness varies in different parts of the body. In some places, the deep fascia gives attachment to underlying muscles; but mostly, the muscles are able to contract and move freely underneath the fascia. Over flat muscles, the deep fascia is not thick or dense. This factor is helpful to muscles which otherwise would be restricted by the fascia. However, in places where the deep fascia passes over bone, it blends firmly with the periosteum. In some parts of the body, extensions from the internal surface of deep fascia, cover deeper lying structures such as the muscles and neurovascular bundles. Such extensions form the ***investing fascia*** (Fig. 2.5).

In the limbs, the deep fascia sends in ***intermuscular septa*** (Fig. 2.5) (plural,septa; singular,septum). Each limb is more or less a cylinder. So, the deep fascia is also a cylinder, running around the internal structures. Almost in the middle of the limb is the bone(s) of the region. The muscles which are attached to the bone(s) are present as a bulk around the bone(s).Very often, muscles with similar function are present adjacent to each other or closely. The deep fascia sends in thick sheets to attach to the bone(s) in such a way that these sheets form the intermuscular septa and muscles of a particular function are within a ***fascial compartment*** (Fig. 2.5)

Near the joints, especially the wrist and ankle, the deep fascia becomes extremely thick and forms the ***retinacula*** (singular, retinaculum). Retinacula are actually thick bands that spread across the particular area and hold the tendons of the area in place. Otherwise, the tendons will bow string during flexion-extension movements of the concerned joints.

> Deep fascia is absent in some sites. In the face and scalp where compression by deep fascia will be a factor of hindrance, it is absent. Though there is some deep fascia over the muscles of the anterior abdominal wall, it is so thin that it is usually discerned to be absent.

Subserous Fascia

This is the fascia with some amount of fat, present between the body wall and the serous membranes of the concerned body cavity. It is an extension of deep fascia.

- The fascia between the thoracic body wall and the pleura (the serous membrane of the thoracic cavity) is the ***endothoracic fascia***.

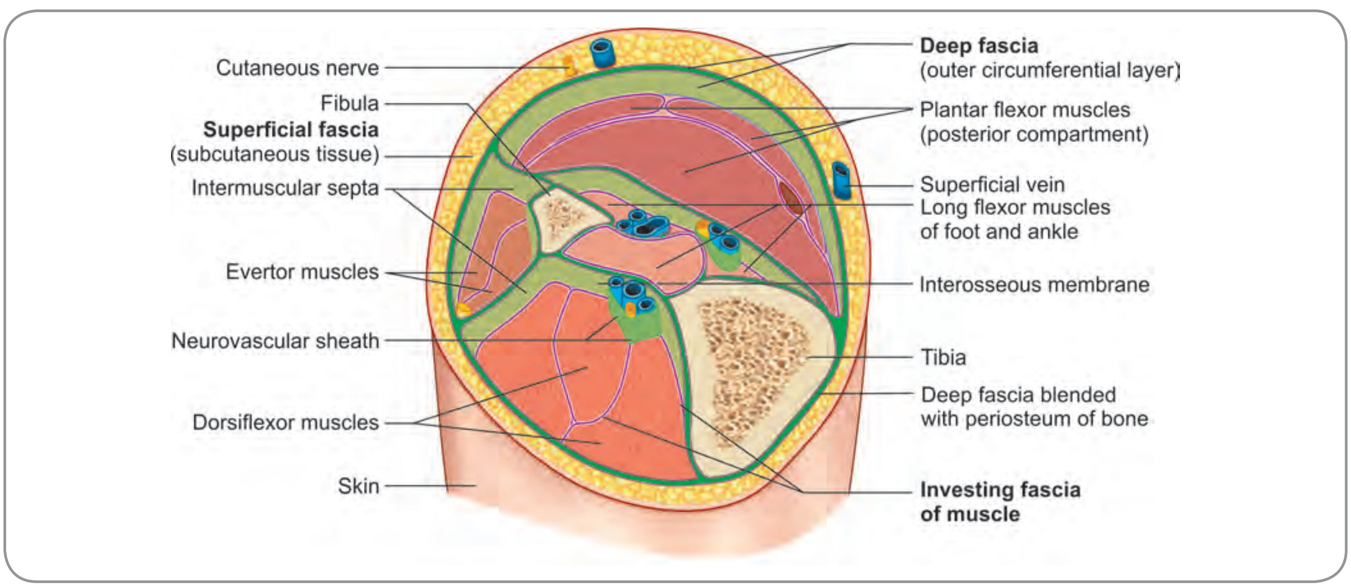


Fig. 2.5: Scheme to show fascia and intermuscular septa as seen in lower limb

- The fascia between the abdominal body wall and the peritoneum (the serous membrane of the abdominal and pelvic cavities) is the ***extraperitoneal fascia***; it is sometimes called by two different names, the ***endoabdominal*** and ***endopelvic fascia*** in the abdominal and pelvic areas respectively.

Serous Membranes and Bursae

Serous membranes are thin, delicate connective tissue membranes present in areas/locations which require lubrication One surface of this membrane is capable of secreting fluid that acts as the lubricant. Such serous membranes surround important organs and structures of the body.

The serous membrane surrounding the lungs is the ***pleura***, the one surrounding the heart is the ***pericardium***, the one surrounding the organs of digestive system is the ***peritoneum*** and those which surround the tendons are the ***tendon sheaths***.

A serous membrane, when surrounding a structure, has a special and unique arrangement. It does not surround a structure as an envelope would cover its contents; but it is like the structure trying to get into the folds of a balloon. Let us imagine a balloon, which instead of air, is filled with little amount of oil. The balloon lies; and the structure to be protected lies next to it. The structure punches into the balloon; the balloon wraps around the structure. Now, the balloon that has wrapped around, comes to have two layers, which are continuous with each other. The inner layer that is close to or approximated to the structure is the ***visceral layer*** and the ***outer layer*** (which usually is approximated to the body wall) is the ***parietal layer*** (Latin.paries=wall). The visceral layer, since approximated to the structure, will have the same ***bends and curves***; the parietal layer, since approximated to the body wall, will appear to be a part of the wall itself. However, the continuity between the two layers is maintained and it can well be understood that a small, narrow cavity exists between the two. This is the concerned ***serous cavity***, called by varied names as according to the region (the ***pleural cavity,*** the ***pericardial cavity*** and the ***peritoneal cavity***) The surfaces of the visceral and parietal layers, which are towards the cavity, are secretory; the cavity has minimal amount of fluid (pleural or pericardial or peritoneal fluid) that acts as a lubricant and helps in free movement of the internally placed structure or organ.

A similar situation occurs in the case of the tendon sheaths too. Long tendons of muscles (especially in the limbs) pass over bones and across several firm structures. As they frequently move, these tendons are subject to friction. To provide lubrication and to avoid friction, the tendons are wrapped around by tendon sheaths in the same manner that the balloon is wrapped around a structure. The tendon sheath is a double layer cylinder (due to the fact that the tendon itself is a cylindrical structure) with visceral and parietal layers.

Going back to the appearance of the balloon, it can be seen that the place where the parietal and visceral layers are continuous with each other, there appears to be a double folded attachment that suspends the structure from the body wall. Such suspensions are called the ***mesenteries*** (singular, mesentery) in general; their specific names vary according to the area/region – ***mesocardium*** in relation to the pericardium, ***mesogastrium*** in relation to peritoneum of stomach, ***mesentery*** in relation to peritoneum of intestines and the ***mesotendons*** in relation to the tendon sheaths. Blood vessels and nerves to the concerned structure pass through the mesenteries

Bursae

Bursae (singular, bursa; Latin, bursa=purse) are small sacs of serous membranes present in areas of the body which are prone for repeated friction. These sacs are interposed between structures which rub against one another. ***Subcutaneous bursae*** are between skin and underlying bony prominences. ***Subfascial bursae*** are beneath deep fascia. ***Subtendinous bursae*** are between tendons and bones.

Added Information

- The dermis corresponds to the animal hides.
- The dermis has two layers namely, the ***thinner papillary layer*** and the ***thicker reticular layer***. The superficially placed papillary layer is made up of areolar connective tissue and gives out finger-like projections called the ***dermal papillae***. These papillae indent the overlying epidermis. On the palms and soles, there are also larger dermal mounds which elevate the overlying epidermis into epidermal ridges called the ***friction ridges***. Friction ridges (also called papillary ridges or surface ectodermal ridges) increase friction between, on one side, the skin surfaces of palms and soles and on the other, the surfaces which come in contact. Thus, the gripping ability of the hands and feet are found to be increased.
- The patterns of these friction ridges are genetically determined and are unique to any individual. They form the fingerprints and the footprints. These prints, especially the fingerprints, form the basis for personal identification. Study of finger and footprints is called ***dermatoglyphics***.

contd...

Added Information *contd...*

- The matrix of the reticular layer of dermis has bundles of collagen fibres. The bundles run in different planes and also in different directions, though most of them tends to run parallel to skin surface. The regions between the bundles form lines of cleavage or the tension lines of skin.
- Flexure lines are also seen over the skin. These result from continual folding of the skin, especially over the joints; at these places, the dermis is attached tight to the deeper structures. Such flexure lines are seen on the wrists, palms, fingers, soles and toes.
- Skin colour is predominantly due to a pigment called ***melanin***. The carotene and haemoglobin are two other pigments which contribute to the complexion. Melanin is synthesized in the melanocytes of the epidermis and is then moved to the keratinocytes (which also are in the epidermis).
- Melanocytes in the basal layer of the epidermis have several processes which touch the keratinocytes Melanin produced in the melanocytes is transferred to keratinocytes through these processes. Melanin granules accumulate and form a shield like layer on the supe ficial aspect of each keratinocyte. It is this shield that prevents ultraviolet rays from reaching DNA of underlying cells.
- The colour of melanin ranges from yellow to red to black. Though melanin passes into keratinocytes, small accumulations of melanin can oocur in different layers of the epidermis. These accumulations appear as freckles or as moles.
- Keratinocytes (Greek. Keras=horn, kytos=cell) keep moving up towards superficial layers As they reach the granular layer, being deprived of nutrition from underlying dermal capillaries (due to distance), they gradually die. So, those keratinocytes in the superficial layers are dead cells. Their nuclei and organelles are subsequently digested away by lysosomal action.
- Keratinocytes produce keratin, which is a fibrous protein present in epidermis hair, nails and horns. As the keratinocytes move up, they produce keratin which eventually fills up the whole cell because by then all other organelles of the cell are digested away. Keratin has large amounts of sulphur and is insoluble in gastric juice. It gives the epidermis protective properties The white lines which are made when we stroke our skin are due to keratin accumulation. Production of keratin is increased when skin is dry and experiences friction.
- In 'so called' white people, melanin in the keratinocytes is digested away by lysosomes a short distance from the basal layer. They, therefore, appear less dark in complexion. In others, melanin is not digested and is present in keratinocytes throughout the epidermis.
- When skin is exposed to solar ultraviolet rays, there is a build up of melanin as a protective measure; this is called ***sun tanning***.
- In the horny layer, keratinocytes have keratin and thick plasma membranes. These two features protect against skin abrasions, minor injuries and penetration. Glycoprotein molecules present between the keratinocytes provide water proofing property.
- Epithelial cells are present in the hair bulb. They multiply and help in hair growth.
- Melanocytes at the base of the hair follicle synthesise melanin and this is transferred to the cells of the hair root. Thus, hair gets colour. Graying occurs when melanin production is reduced or stopped (usually by a genetic direction that occurs only after the age of 40). Melanin in the cells of hair shaft is then replaced by air bubbles which appear white or silvery.
- The shape of the hair shaft is responsible for the hair types as we describe them. If the shaft is round in cross-section, hair is straight; if oval, hair is wavy; if ribbon-like, the hair appears kinked.
- At the proximal end of the nail body (the root region), the nail bed thickens to form the nail matrix. This is the actively growing area and is responsible for the g owth of the nail. The nail matrix is thick and does not show out the dermis. Hence, the nail overlying the matrix region appears white. This is the white crescent which is often seen on the proximal aspect of the nail plate and is called the ***lunula***.
- The intermuscular septa forming the fascial compartments of the limbs have an important functional role. The compartments restrict outward bulging of the bellies of the muscles inside during contraction. This prevents loss of muscle energy and helps in such energy getting focused to the area of action/movement.
- The intermuscular septa and their restriction on the outward expansion of the muscles also have another function. The compression caused by the fascia on the muscles, in turn causes compression on the internal veins and blood is then pushed out. Due to the presence of unidirectional valves in the veins, b ood flows towards the heart. Along with the veins and their valves, the fascia and the muscles act as parts of a fascio-musculo venous pump to help in venous return.
- Apart from intermuscular septa and retinacula, other modifications of deep fascia include the palmar and plantar aponeuroses, fascial sheaths around neurovascular bundles (example, carotid sheath), fascial sheath for certain muscles (example, psoas fascia), fibrous sheaths for flexor tendons of digits (fibrous flexor sheaths) and interosseous membranes of forearm and leg.

Clinical Correlation

- The blood vessels in the dermis are extensive; it is possible for these vessels to hold about 5% of the total blood of the body. When other parts of the body need more blood (such as the muscles during exercise), the dermal blood vessels are constricted and blood is shunted to other parts. On hot days, the dermal vessels engorge with blood; this causes radiation of heat from the body surface, thus leading to a cooling effect.
- The tension lines are longitudinal in the limbs and in the head; they are circular in the neck and trunk. Surgical incisions should preferably be made parallel to the tension lines so that the skin does not gape much and heals better. When incisions are made across the cleavage lines, healing is delayed.

contd...

Clinical Correlation *contd...*

- Dead keratinocytes in the superficial layers of epidermis fall off everyday; the time taken for a keratinocyte from its appearance in the basal layer to its final falling off is about 40 days. Thus we get a 'new' epidermis once in about 40 to 45 days Normally, production of new keratinocytes in the basal layer and their 'fall off' in the horny layer are well balanced.
- Excessive thickening of the epidermis when there is continuous rubbing and friction; this is called ***callus*** or ***callosity*** (other names, tyloma, keratoma, poroma; Latin.callosus=thick skin).
- Strong friction of short duration causes the epidermis to separate from the dermis. Fluid oozing from dermis may form a small collection beneath the epidermis; the condition is a ***blister***. When the blister is large, it is called a ***bulla***.
- Extreme stretching of the skin (in excessive weight gain, in pregnancy) can tear the dermis. These tears are seen as white scars; they are called stretch marks or striae (Greek. Strie=streaks).
- When the individual is said to gain weight, fat starts getting deposited in the subcutaneous layer; the distribution of such deposits varies in males and females; in females the initial deposits occur in thighs and breasts and in males in the anterior abdominal wall
- Melanin prevents the ultraviolet rays of sunlight from penetrating deep into the skin and thus affords protection from skin cancer. The melanin content is found to be less in people living in colder regions of the globe. The little amount of UV rays which they receive during their short summer is necessary for stimulating the epidermis to synthesise vitamin D and the low content of Melanin allows UV penetration. To people of the tropics, more than necessary sunlight is available for vitamin D synthesis and excess UV penetration is cut off by the higher content of melanin.
- The blood vessels in the hair papilla supply nutrients to the growing hair If the papilla is destroyed through injuries and trauma, follicle can no longer produce hair.
- When the arrectores pilora muscles contract, hairs stand erect and the skin surfaces gets small depressions. This produces the ***goose-bumps***; cold or fear causes them. In case of animals, goose bumps cause a layer of air to get trapped in the fur and provide warmth. Also, an animal in such a state appears larger than usual, affording some kind of protection from the enemy.
- The sebaceous glands are stimulated by sex hormones; they function maximally around puberty and whenever hormonal secretions are increased. When sebum production exceeds the amount that can be taken to the surface by the duct, sebum collects in the gland Since sebum itself is thick and greasy, it tends to block the duct. The hardened sebum blocking the duct is seen on the surface as a ***white-head***. When the same material oxidises (due to external exposure) and subsequently dries up, it converts into a ***black-head***. When blocked sebaceous glands are infected by bacteria, pimples occur.
- Seborrhoea is a condition caused by excessive production of sebum. Due to hormonal stimulation or due to excessive dryness (when the sebaceous glands make an attempt to compensate by producing their oily secretions), sebum is produced in abundance and usually flows over the scalp as a thin layer. This layer dries up and flakes off causing the popularly dreaded 'dandruff'.
- Heat induced sweating starts on the forehead and then spreads down the rest of the body. On the contrary, emotion induced sweating (often called the cold sweat) starts on the palms, soles and axillae and then spreads to the other parts. Fear, nervousness, anxiety and embarrassment cause emotional sweat.
- Spread of infection or tumour is prevented by the intermuscular septa
- Surgeons while performing different surgeries attempt to identify potential spaces between adjacent fasciae. These spaces can be utilised to access deeply placed structures and to have adequate area for organ movements.
- Administration of certain drugs is done intradermally. Testing of sensitivity for certain chemicals and drugs (example, penicillin) is also done by giving intradermal injections.
- ***Burns:*** This is the most important damage that skin is often subjected to, either in minimal or maximal amount. A burn is a tissue damage caused by heat, electricity, chemicals, radiation or extreme friction. When the skin is damaged, body fluids are lost both by excessive evaporation and inflammatory secretion. Body dehydrates and salts are also lost. Replacement of fluids is the most important measure in burns treatment.
- ***Burns*** are classified according to the depth of damage. If only the epidermis is involved, it is ***first-degree***; if epidermis and upper portion of dermis are involved, it is ***second-degree***; if both epidermis and dermis are involved in their complete thickness, it is ***third-degree***. First and second degree burns are known as ***partial thickness burns*** and third degree as ***full thickness burns***.
- ***Skin cancer:*** This is the most common type of cancer in the western world. The most important risk factor is over exposure to solar ultraviolet light. Different types of skin cancer occur depending upon the involved cells. When basal cells (basal cell carcinoma) and keratinocytes (squamous cell carcinoma) are involved, it is less dangerous. The most dangerous is malignant melanoma which is cancer of melanocytes.

Multiple Choice Questions

1. The skin along with its specialised structures and appendages forms the:
a. Integumentary system
b. Dermal system
c. Sebaceous system
d. Eponychial system

2. Wrinkle lines of the body are determined by:
a. Pattern of fibres in the dermis
b. Thickness of dermis
c. Thickness of epidermis
d. Presence of sweat glands

3. Hairs act as touch receptors because:
a The hair follicle is slanting
b. Root hair plexus surrounds the hair bulb
c. Arrectores pilorum muscle is attached
d Hair shaft has keratinised cells

4. Nail plates appear pink due to:
a. Capillaries in the underlying dermis
b. Capillaries in the underlying nail bed
c. Covering of nail folds
d. Colouring material in their keratin layers

5. Thickenings of deep fascia which hold tendon in place are:
a. Serous membranes
b. Retinacula
c. Intermuscular septa
d. Subtendinous bursae

ANSWERS

1. a **2.** a **3.** b **4.** a **5.** b

Clinical Problem-solving

Case Study 1: A 12 year-old girl developed extensive white-heads and black-heads over her face. Her doctor, while suggesting treatment, also assured that there was nothing abnormal.

- What caused white-heads and black-heads?
- In what way is it a normal process?
- Which structures of the body are involved in the process?

Case Study 2: 15-year-youth had extensive sweating. Looking that his palms and soles were becoming wet, his father asked him what the cause for his anxiety was. The boy said that it was only the atmospheric heat which caused the sweating. The father refused to believe the boy.

- Was the father correct?
- What did the son's hands and feet indicate to the father?
- How can heat-induced sweating can be differentiated from anxiety-induced sweating?

(For solutions see Appendix).

Chapter 3

Muscles

Frequently Asked Questions

- What are the three basic types of muscles?
- What are the differences between the contractile and the non-contractile portions of a muscle?
- Give examples of pennate muscles.
- Define (a) Prime mover, (b) Synergist.
- Why is cardiac muscle, sometimes called visceral muscle?

The human body contains a very large number of muscles; they form the major bulk of limbs and some other parts of the body and contribute to the various movements which the individual can make. Thus the muscles are also part of the locomotor apparatus. Study of muscles is called ***myology***.

Muscles have been so named (Latin.mus=mouse) because many of them resemble the shape of a mouse. Muscles (more so the striated muscles) have a bulkier body and a thinned out tendon; thus they appear to have the shape of a mouse, with the tendon looking like a tail. Contractility (to be able to shorten and lengthen itself by contractions) is the important property that underlines all muscles.

Muscles are of three types, namely, (1) ***striated***, (2) ***non striated*** and (3) ***cardiac muscles***. The striated muscles are so called because of the presence of lines or striations when this tissue is seen under the microscope. No lines are present in the tissue of other muscles and hence, such muscles are called nonstriated muscles. Cardiac muscle is found in the heart.

STRIATED MUSCLES

Striated muscles are otherwise called

- ***Striped muscles:*** Due to the presence of striations or stripes;
- ***Skeletal muscles:*** Due to their attachments to bones;
- ***Somatic muscles:*** Due to their presence in the body wall, limbs and structures developmentally related to the body wall;
- ***Voluntary muscles:*** Due to the fact that they can be made to move at will.

They form the major bulk of the human body amounting to about 40 to 50 percent of the total body mass. They are responsible for various body movements and thus give energy. For this reason, they have been called the ***engines*** or ***motors*** of the body.

Each muscle has a bulky and fleshy central portion called the ***belly***; this is the actively contracting part. The ends of the muscle are usually thinner and non-contractile; this is the portion by which the muscle is attached to the bone (sometimes to cartilage or ligament). When the non-contractile portion is cord-like, it is called a ***tendon*** (Latin.tendo=to stretch out); when it is flattened, it is an ***aponeurosis*** (Fig. 3.1) (Greek.apo=from; neuro=sinuous).

The tendon and aponeurosis consist of dense connective tissue and have a shiny, yellowish-white colour in sharp contrast to the reddish-brown colour of the belly. Though both ends of the muscle may have tendons, when the tendon is very short, the muscle appears to be directly

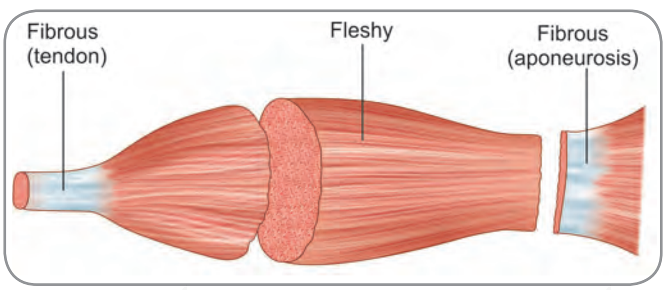


Fig. 3.1: The be ly and the tendinous cross-sections-comparison

attached to the bone. Tendons and aponeuroses (sing. aponeurosis, pl. aponeuroses) have lower metabolism and hence, are less richly supplied with blood vessels than the belly portion. The belly and the tendinous portions have is contrasting properties; the belly has highly specialized fleshy fibres, is contractile, extremely vascular, resistant to infection but highly susceptible to pressure or friction; the tendinous portion is fibrous, unspecialised, inelastic, less vascular, also sloughs away rapidly in infection but is designed to withstand infection (Fig. 3.1).

For sake of convenience, the two ends of a muscle are described by two names. ***Origin*** is that end which remains fixed during contraction; ***insertion*** is the other end that moves during contraction. The insertion is pulled towards the origin, when contraction causes movement. In the muscles of the limbs, origin is usually proximal and the insertion is distal. However, the terms origin and insertion do not hold a water-tight compartment. In some muscles, both ends move during differing actions. In some other muscles, movements occur at both ends and then it is difficult to define.

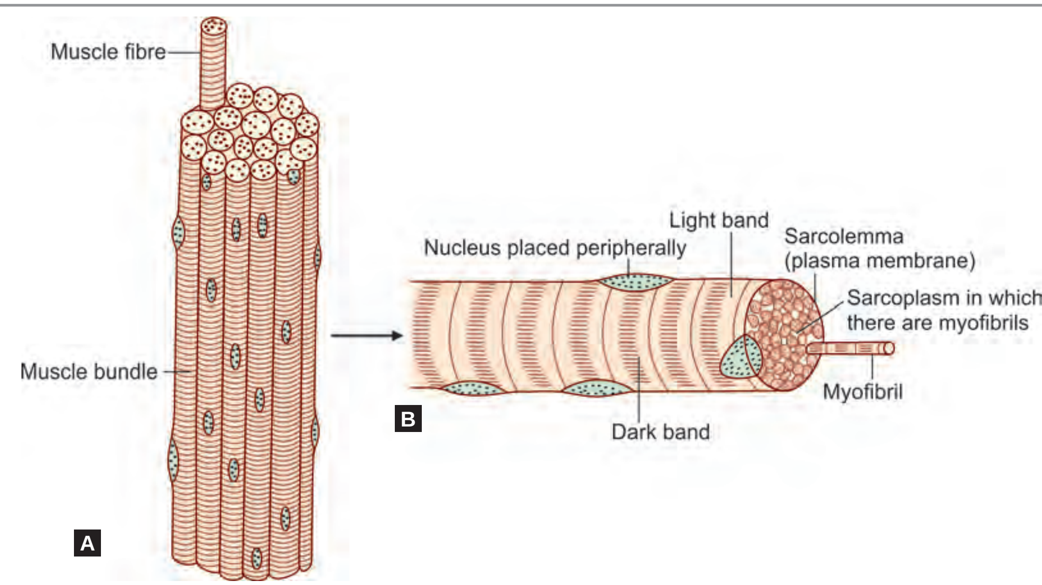
Dissection

Skeletal muscles are seen as red, soft structures. After cleaning a muscle, try to lift it up carefully from its bed. The neurovascular bundle entering the muscle can be made out. Slowly and gradually, by blunt dissection, trace them to the main nerve trunk and parent vessels. Attempt to see the nerve supply and blood supply to a muscle wherever possible

When a striated muscle is studied, it can well be seen that the cross-sectional area of a tendon is much less than that of the fleshy belly. This factor is of great importance to the functioning of a muscle. Many of the striated muscles of the body run from one bone to another across a joint. When the muscle contracts, the two bones are approximated and movement occurs at the joint. Hence, these muscles are defined to act upon joints. It is usually at the tendon that the pull of the muscle is exerted. As the tendon converges to a smaller area of attachment, the force of muscle pull is concentrated and focused. This will make the movement smoother, faster and more powerful. When the muscle is attached to the bone directly by means of fleshy fibres, the force is low and wide spread. In many muscles, such a fleshy attachment can be seen at the origin. If we consider that the origin remains fixed and the insertion (the tendinous portion of the muscle) moves, cumulative addition of force occurs from the origin to insertion as the muscle contracts and all the force is focused on the tendinous insertion to give an effective pull. The same fact that force is concentrated at the tendinous attachments is also responsible for producing marks on the bone. Points of fleshy attachments do not produce bony ridges or tubercles but points of tendinous attachments have bony prominences like ridges, tubercles, facets or prominences.

Structure of Striated Muscle

Each striated muscle is made up of numerous ***muscle fibres*** (myofibrils) (Fig. 3 2). Each muscle fibre, actually, is a muscle cell called the ***myocyte*** (Greek.myo=muscle, cyte=cell). It is an elongated and cylindrically shaped multinucleated cell with cross striations. It has a ***sarcolemma*** (the cell membrane of the myocyte; (Greek. sarx=flesh; lemma=husk/skin) which encloses the ***sarcoplasm*** (cytoplasm of the myocyte). Within the sarcoplasm, several nuclei can be seen arranged at the



Figs 3.2A and B: Structure of skeletal muscles **A.** Muscle bundle **B.** Muscle fibre

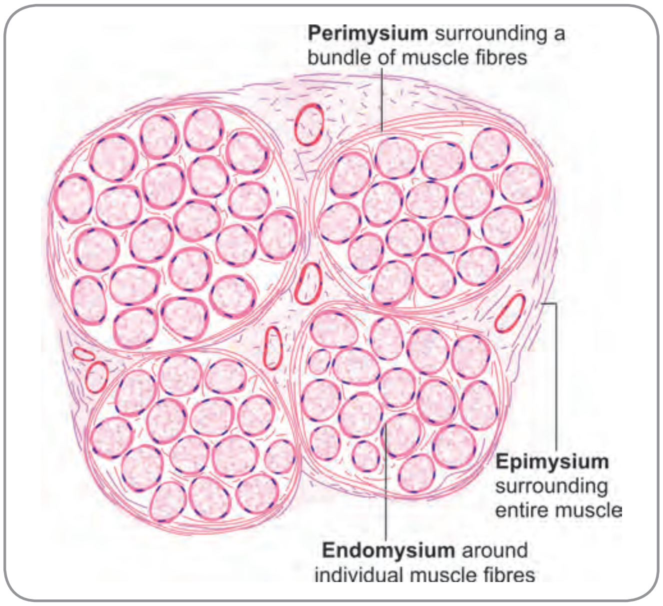


Fig. 3.3: Connective tissue present in relation to skeletal muscle

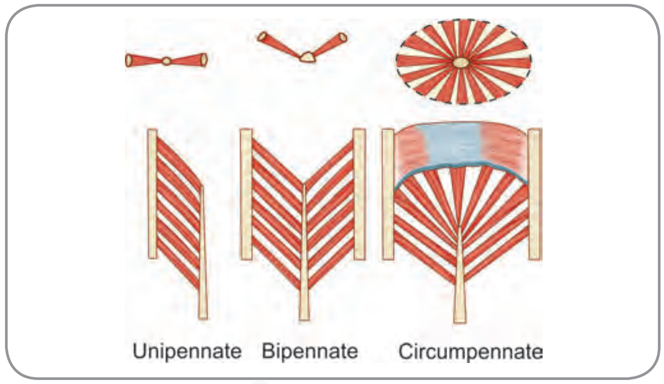


Fig. 3.4: Skeletal muscle-shape and architecture

periphery beneath the sarcolemma. Each muscle fibre is surrounded by some amount of loose connective tissue called the ***endomysium*** (Fig. 3.3) (mysia=muscle). Around a bunch of fibres, there is another sheath of connective tissue called the ***perimysium.*** All the muscle fibres which are enclosed within a sheath of perimysium form a single bunch and this bunch is the ***muscle fascicle*** *(*Greek.Fasikle=bundle). Many fascicles join up to form a muscle. Around the entire muscle is yet another sheath called the ***epimysium.*** The epimysium sometimes blends with the layers of deep fascia present near the muscle. The presence of connective tissue in the form of endo, peri and epimysia permits gliding and swelling of the individual fibre or bunch of fibres enclosed.

Each individual skeletal muscle fibre is, as already noted, a multinucleated muscle cell. The diameter of skeletal muscle fibres in different parts of the body ranges from 10 to 100 microns. This is about ten times larger than the average body cell. Similarly, the length of the fibre is many centimeters. However, each muscle fibre is a fusion of several embryonic muscle cells and therefore, has several nuclei (the separate nuclei of separate embryonic cells have all become the nuclei of the fused muscle cell). Inside each fibre are the myofibrils which are responsible for the contraction mechanism.

The individual muscle fibres (in a way, the fascicles, because the fibres are grouped into fascicles and the fascicles can be seen by the naked eye) are arranged either parallel or at an angle to the long axis of the muscle.

Muscles are classified according to the direction of fibres which in turn also determines the shape to a large extent.

- ***Flat muscles:*** Muscles whose fibres run parallel. Examples are external oblique and Sartorius.
- ***Pennate muscles (Fig. 3.4):*** Muscles whose fibres run oblique to the long axis (Latin.pennatus=feather); when the tendon lies on one side and the fibres run obliquely to it, it is ***unipennate***; when the tendon lies in the centre of the muscle and the fibres run to it from two sides, it is ***bipennate***; when a series of bipennate structures lie alongside one another and form a big muscle or when the tendon lies in the centre and the fibres pass to it from all sides, it is ***multipennate***. Examples are Extensor digitorum longus (unipennate), rectus femoris (bipennate) and deltoid (multipennate) (Fig. 3.5).
- ***Fusiform muscles:*** Muscles with a round, thick belly tapering to thin ends thus making a spindle shape. Example is the biceps brachii.
- ***Convergent muscles:*** Muscles which are broad and end in a single tendon. Example is the pectoralis major.
- ***Quadrate muscles:*** Muscles which have four equal sides. Examples are the Quadratus lumborum and the pronator quadratus.
- ***Circular muscles:*** Muscles whose fibres surround on opening, thus constricting the opening on contraction. Example is the orbicularis oculi. The general name for a circular muscle is a sphincter (Greek. Sphinct=squeeze), because contraction of the muscle causes ***constriction*** or ***squeezing*** of the opening. However, in practice, the term ***'sphincter'*** is applied to circular muscles which surround specific openings. An example is the anal sphincter.
- ***Multiheaded/multibellied muscles:*** Muscles which have either more than one head of attachment or more than one contractile belly Examples are biceps brachii and triceps brachii.

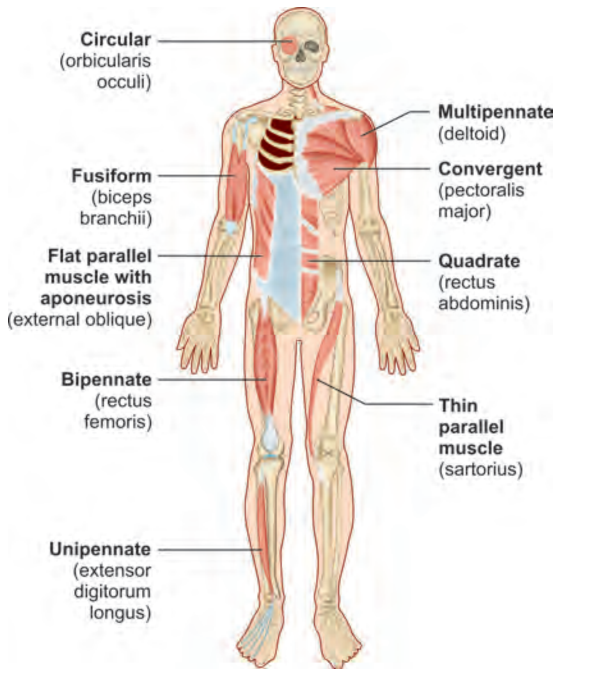


Fig. 3 5: Muscle-shape and architecture

The arrangement of the fibres and the fascicles determines the power and range of movement of the muscle. When a muscle contracts, it shortens by one half or one third of its resting length; so, a muscle, whose fibres are parallel to the long axis and thereby the line of pull, will bring about greater movement than the one whose fibres are oblique. But this movement is not the most powerful. The power of a muscle depends on the total number of fibres it contains. And power is more if the contraction is oblique to the long axis. So pennate and convergent muscles are more powerful.

Names of Muscles

Each muscle has a name. A muscle is named after considering its action, its shape and size, and the region in which it lies. Any of these factors can be associated with the name and the name usually consists of two or more words based on these characteristics. However, from the name of a given muscle, it is easy to understand its location and to some extent its action.

Names Based on Region

The region on the front of the chest is called the ***pectoral region***. There are two muscles in this region. The larger of the two is the ***pectoralis major*** and the smaller, the ***pectoralis minor***

The region of the buttock is called the ***gluteal region***. It contains three large muscles that are given the names ***gluteus maximus*** (largest), ***gluteus medius*** (intermediate in size) and ***Gluteus minimus*** (smallest). In each of the above examples, it can be noted that the first word in the name refers to the region concerned, and the second to the relative size of the muscle itself.

The muscles close to the spine of the scapula, have this indication in their names; the one above the spine is ***supraspinatus*** (superior to spine) and the one inferior is ***infraspinatus*** (inferior to spine).

Names Based on Shape and Size

Muscles which are straight are given the name ***rectus*** (compare with 'erect'). One such muscle present in the wall of the abdomen is called the ***rectus abdominis***. Another in the thigh is called the ***rectus femoris*** (Femoral=thigh). A round muscle goes by the name ***teres***. There is a ***teres major*** and another ***teres minor***; the former is larger than the latter (Fig. 3.5).

Over the shoulder is a strong triangular muscle called the ***deltoid,*** named after the Greek letter *delta*, which is shaped like a triangle. A quadrilateral muscle present in the lumbar region is called the ***quadratus lumborum***. Similarly, a small muscle in the forearm, with a quadrilateral shape is called the ***pronator quadratus.***

A muscle that appears linear is called ***longus; Longus capitis*** and ***longus colli*** are examples. ***Longissimus*** is a term to denote the 'longest' and ***latissimus*** to denote 'broadest'.

Most muscles have a fusiform shape. The central thicker part is muscular and is called the ***belly***. The ends are usually tendinous. Some muscles have two (or more) bellies each with a distinct origin; these distinctly arising parts are called the heads. A muscle having two heads is given the name ***biceps*** (bi=two;cep=head) There is one such muscle in the arm and another in the thigh. The one in the arm is the ***biceps brachii*** (brachium= arm) and that in the thigh is the ***biceps femoris*** On the back of the arm, is a muscle that arises by three heads. It is called the ***triceps***. On the front of the thigh, is a muscle that has four heads and is called the ***quadriceps femoris***. Yet another muscle with two bellies is called ***digastric*** (di=two, gaster=belly).

Names Based on Attachments

Skeletal muscles are attached to bones. Many muscles are named after such attachments. ***Sternocleidomastoid*** is a muscle found in the neck region. It is so named because of its attachment to the sternum (sterno) and clavicle (cleido) at one end and the mastoid process (mastoid) of the temporal bone at the other end.

Names Based on Action

Muscles that produce flexion may be named ***flexors*** and those that produce extension, ***extensors***. Similarly, a muscle may be an ***abductor***, an ***adductor***, a ***supinator*** or a ***pronator***. In each case, the word indicating action

is followed by another word indicating the part on which the action is usually produced. For example, on the back of forearm is a muscle that is an extensor of the digits: it is called the ***extensor digitorum***. A muscle that produces abduction of the thumb is the ***abductor pollicis*** and the one that produces abduction of the big toe is ***abductor hallucis***.

Composite Names

When more than one muscle performs the same action, all of them will qualify for the same name. In such cases, the second part of the muscle's name gives an indication of either the location, shape, size or any other distinguishing feature. On the front of forearm there are two muscles that produce flexion at the wrist (or carpus). One of them that lies towards the medial (or ulnar) side is called the ***flexor carpi ulnaris.*** The second muscle lies towards the lateral (or radial) side and is called the ***flexor carpi radialis***. In the forearm there are two muscles which contribute to pronation. One of them is a long muscle and hence is called the ***pronator teres***; the other is small and quadrangular, thus getting the name ***pronator quadratus.***

It can, therefore, be seen that the addition of a third or fourth term to the name attempts to distinguish between muscles of similar function. On the back of the forearm, are two radial extensors of the wrist; since both are radial (radialis) and both are extensors of the wrist (extensor carpi), yet another term is required to distinguish between the two. The length of the muscles is taken into consideration and the longer is called the ***extensor carpi radialis longus*** and the shorter is named as the ***extensor carpi radialis brevis***. On the medial side of the thigh, are three muscles which produce adduction of the thigh. Because of variations in size, they are called the ***adductor longus***, the ***adductor brevis***, and the ***adductor magnus.***

The relative position of a muscle can also contribute to its name. Of the two muscles which are present in the forearm and are responsible for flexing the fingers, one is closer to the surface than the other; so, the former is called ***flexor digitorum superficialis*** and the latter ***flexor digitorum profundus*** (Latin.profundo=deep;French. profundeur=depth).

Action of Skeletal Muscles

Movements occur, not by the action of a single muscle but by a coordinated effort of many muscles. When an individual bends the elbow, it can be noticed that the muscles in the front of arm should be shortening in length whereas the muscles at the back of arm should be lengthening at the same time. It is essential, therefore, that various muscles act in harmony to produce various kinds of movements.

Depending upon the contribution made by a particular muscle to a particular movement, it can be

- ***Prime mover:*** When it is the chief muscle responsible for a particular movement. Example: Quadriceps femoris is a prime mover for extension of knee.
- ***Agonist:*** When it is the same as the prime mover for a particular movement.
- ***Antagonist:*** When it opposes the action of the prime mover (for that movement) Example: Biceps femoris is an antagonist for extension of knee.
- ***Fixator:*** When it stabilises (fixes) the origin of the prime mover so that the latter can act efficiently. Example is when the muscles of the shoulder girdle like the rhomboideus major and rhomboideus minor which fix the scapula so that deltoid muscle can act better on the shoulder joint.
- ***Synergist (Greek. syn=together, ergon=work):*** When it helps the prime mover to act efficiently by performing a similar but intervening action. A prime mover sometimes crosses another joint before reaching its main point of action, because of which unnecessary movements can occur in the intermediate joint. To avoid this kind of a movement, another muscle contracts and fixes the intermediate joint. This is then a synergist to the prime mover. When flexor digitorum profundus crosses the wrist joint before reaching the fingers, it can cause flexion of the wrist. But its efficiency and power will be reduced. Flexor carpi ulnaris and flexor carpi radialis contract and fix the wrist so that flexor digitorum profundus can act efficiently.

Note: The same muscle can act in different capacities during different movements.

NON STRIATED MUSCLES

Non striated muscles are otherwise called

- ***Smooth muscles:*** Due to absence of striations;
- ***Visceral muscles:*** Due to their occurrence in the visceral organs;
- ***Involuntary muscles:*** Because they are not under voluntary control.

Many of them occupy the walls of internal organs like the stomach, intestines, urinary bladder and also walls of blood vessels.

CARDIAC MUSCLES

These are muscles exclusively present in the walls of the heart chambers. They are striated like the skeletal muscle but their contraction is not under voluntary control. Along with the smooth muscle, cardiac muscle is also sometimes called the ***visceral muscle*** since it is present in a viscus, namely the heart.

Added Information

- **Shunt–spurt muscles:** When a muscle exerts its pull along the line that is parallel to the axis of the bones to which it is attached, it is at a disadvantage. Instead of producing effective movement, most of its force is lost on trying to keep the joint that it crosses intact. In other words, the muscle is diverting most of its force to resist dislocation of the joint. So, its power of movement is reduced. The muscle, in such an instance, acts as a shunt muscle. Let's see an example. The upper limb is hanging by the side of the body. The deltoid , then, is a shunt muscle. Its power is lost in trying to resist dislocation of shoulder. The same muscle can act as a spurt muscle at a different instance. When a muscle exerts its line of pull oblique to the bone it moves, the movement is faster and more effective. When other muscles have initiated abduction of the arm, the line of pull of deltoid becomes oblique to the humerus and is more effective. Thus, deltoid in this instance becomes a spurt muscle.
- The structural unit of a skeletal muscle is the ***striated muscle fibre***; the functional unit is a ***motor unit***.
- The number of fibres in a motor unit varies according to the size and function of the muscle. Large motor units occur in muscles that have gross and powerful actions. Examples are the large trunk muscles and thigh muscles where a single neuron supplies several hundred muscle fibres. In muscles that produce precision movements the motor units have only a few muscle fibres.

Development

- All muscle tissue (except for rare exceptions) develops from embryonic mesoderm cells called ***myoblasts***.
- Myoblasts that form future skeletal muscles fuse together to form the multinucleated muscle fibres; these fibres then develop myofibrils and filaments thus acquiring the ability to contract.
- Myoblasts that form cardiac and smooth muscles do not fuse. But the individual cells communicate with each other through gap junctions.
- Skeletal muscle fibres are surrounded by satellite cells throughout life; the satellite cells are like the myoblasts. During childhood, the skeletal muscle fibres grow in length and increase in thickness. They cannot or do not undergo division after birth. During adolescence and youth, the satellite cells fuse into existing muscle fibres and help them grow When a muscle is injured, the satellite cells surrounding that muscle and its fibres, fuse together to form new muscle fibres. This capacity for regeneration helps in recovery after injuries but if the injury and damage are severe, the muscle fibres are totally replaced by scar tissue.
- Smooth muscle fibres retain their capacity to divide even after birth and almost throughout life. Because of this, they have a good amount of regenerative and repair capacity.
- Cardiac muscle fibres, like the skeletal muscle fibres undergo no division after birth. They also do not have satellite cells around them. So, they have no regenerative capacity, whatsoever. Because of this, repair and recovery after heart attacks are hampered.

Clinical Correlation

- Muscular dystrophy is a group of diseases wherein muscle fibres undergo destruction due to genetic causes. Fat and connective tissue gradually get deposited in the affected muscles and they appear to be growing in size. But the muscle fibres themselves degenerate and the individual is not able to move, walk, bend or work the muscles in harmony. The most common and the most serious disease of this group is the ***Duchenne muscular dystrophy***, which is a sex-linked recessive disease. It is transmitted by females but almost exclusively affects the males. Between the ages of 2 years and 8 years, the affected boy starts showing out the symptoms of muscular weakness, clumsy movements, inability to stand or walk and frequent falls. Disease progresses from pelvic muscles to shoulder muscles, head muscles and chest muscles in that order. Patients die usually before 25 years of age, due to respiratory muscular failure. Diseased muscle fibres are deficient in a membrane protein called ***dystrophin***. Deficiency causes ext acellular calcium ions to leak into muscle fibres leading to disruption.
- With a rich blood supply, skeletal muscle is highly resistant to ***infection***.
- Due to ***ageing***, connective tissue within skeletal muscle increases and muscle fibres decrease in number. This leads to decrease in muscular efficiency. The body mass also decreases and the body weight in turn. Elderly people shrink in appearance and their muscular strength is reduced.
- ***'Myalgia'*** is the term for muscle pain (Greek.algos=pain). ***Myopathy*** indicates any disease of muscle. ***Spasm*** is sudden involuntary contraction of skeletal or smooth muscles. Injuries, chemical and inflammatory reasons may cause spasms. ***Cramp*** is a prolonged spasm leading to severe pain. ***Tics*** are localised spasms of eye or facial muscles, which usually occur due to psychological factors.

Multiple Choice Questions

1. Muscles are called engines of the body because:
   a. They constitute the bulk of the human body
   b. They provide energy by their contraction
   c. They are spread throughout the body
   d. They are highly vascular
2. The connective tissue covering around a single muscle fibre is:
   a. Perimysium
   b. Endomysium
   c. Epimysium
   d. Micromysium
3. A sphincter is a:
   a. Circular muscle
   b. Pennate muscle
   c. Convergent muscle
   d. Fusiform muscle
4 Muscles occupying the walls of blood vessels are:
   a. Smooth muscles
   b. Cardiac muscles
   c. Somatic muscles
   d. Shunt muscles
5. Skeletal muscle fibres:
   a. Undergo division throughout life
   b. Are surrounded by satellite cells
   c. Have no regenerative capacity
   d. Produce satellite cells during injury

ANSWERS

1. b **2.** b **3** a **4.** a **5.** b

Clinical Problem-solving

Case Study 1: A 5-year-old boy developed difficulty in walking. He is also unable to stand straight and erect. Looking at the boy, his mother felt that she was, in a way, responsible for the condition.

- What disease had affected the boy?
- Why was the mother feeling upset and in what way was she responsible?
- Will the ailment stop at the level of legs or spread elsewhere?

Case Study 2: A 60-year-old man was looking at his old photograph with sorrow. He found that his muscles had reduced in size and were not as powerful as before. He felt he was severely diseased.

- Would you agree with him that he was diseased?
- What is the histological cause for his muscles reducing in size and decreasing in their efficiency?
- What will be the effect on the old man's body weight?

(For solutions see Appendix).

Chapter 4

Cartilages and Bones

Frequently Asked Questions

- How are bones classified? Add a note on long bones.
- What are sesamoid bones? Give an example.
- Write short notes on (a) Bone marrow, (b) Periosteum, (c) Nutrient artery, (d) Atavistic epiphysis, (e) Traction epiphysis.
- Discuss the process of cartilaginous ossification.

CARTILAGES

Cartilage (***or chondral tissue***) is a connective tissue that is firm and elastic but not as hard as the bone. It can be said that cartilage is supplementary to bone. In many parts of the body, cartilage appears first and is then converted into bone. In some parts, it continues to be present throughout life. Cartilage is not supplied by blood vessels and nutrition is by diffusion from adjacent tissue fluids.

As in bone, cartilage is covered by a fibrous sheath called ***perichondrium*** (Greek. peri=around, chondron=cartilage). The articular cartilages of synovial joints do not have perichondrium on their articular surfaces and so are raw cartilages

Cartilage occurs in certain specific locations of the body and is given specific names. These are the as follows:

- ***Articular cartilages:*** Those covering the articular surfaces of the bones.
- ***Costal cartilages:*** Those which connect the ribs to the sternum.
- ***Laryngeal cartilages:*** Those in the larynx (including the epiglottis).
- ***Intervertebral discs:*** Those pieces of cartilage in the discs between vertebrae.
- ***Tracheal rings:*** Those pieces of cartilage present in the trachea.

Apart from these, cartilages are present in the ear and the nose also. The ***nose***, as we call the prominent forward projection in the face, is for a large part, made up of cartilage.

The most characteristic property of cartilage is its ***resilience***. This is the ability to get back to its original shape after being compressed This ability makes pieces of cartilage act as ***buffers*** in areas where friction and compression occur. Resilience of cartilage is due to the fact that it holds lot of water in its matrix.

Cartilage is also capable of rapid growth. It is in abundance in the embryo. Cartilage tissue secretes certain chemicals which prevent blood vessels from growing into it. Thus cartilage is ***avascular*** (devoid of blood supply). It receives its nourishment from the vessels in the perichondrium.

Histology

Cartilage is a connective tissue; like all other types of connective tissue, cartilage also has cells and extra cellular matrix. The cells are called ***chondrocytes***. The extracellular matrix has a jelly-like ground substance and collagen fibres. The glycosaminoglycan molecules (long sugar molecules) in the ground substance have negative charges in them. Water molecules are attracted by these negatively charged areas and water shells surround them. When the cartilage is subjected to compression, the negative charges are pressed against each other and the water shells are forced away. When the negative charges come too close to one another, they repel each other and further compression cannot occur. When the pressure is released, water shells rush back to their negatively charged sites and the cartilage regains its shape.

Histologically, cartilage is classified into three types, namely the ***hyaline cartilage***, the ***white fibrocartilage*** and the ***elastic cartilage***. Each type is distinguished by the type of fibre that dominates the matrix.

Added Information

TYPES OF CARTILAGE

Hyaline Cartilage

Description

Hyaline cartilage is so called because it is transparent (hyalos = glass).

Its intercellular substance appears to be homogeneous, but using special techniques it can be shown that many collagen fibres are present in the matrix.

The fibres are arranged so that they resist tensional forces. Hyaline cartilage has been compared to a tyre. The ground substance (corresponding to the rubber of the tyre) resists compressive forces, while the collagen fibres (corresponding to the treads of the tyre) resist tensional forces.

Calcification of hyaline cartilage is often seen in old people. The costal cartilages or the large cartilages of the larynx are commonly affected. n contrast to hyaline cartilage, elastic carti age and fibrocartilage do not undergo calcification. Although articular cartilage is a variety of hyaline cartilage, it does not undergo calcification or ossification.

Distribution of Hyaline Cartilage

- ***Costal cartilages:*** These are bars of hyal ne cartilage that connect the ventral ends of the ribs to the sternum, or to adjoining costal cartilages. They show the typical structure of hyaline cartilage described above. The cellularity of costal cartilage decreases with age.
- ***Articular cartilage:*** The articular surfaces of most synovial joints are lined by hyaline cartilage. These articular cartilages provide the bone ends with smooth surfaces between which there is very little friction. They also act as shock absorbers. Articular cartilages are not covered by perichondrium. Th eir surface is kept moist by synovial fl uid that also provides nutrition to them.
- ***Other sites where hyaline cartilage is found:***
  - The skeletal framework of the larynx is formed by a number of cartilages. Of these the thyroid cartilage, the cricoid cartilage and the arytenoid cartilage are composed of hyaline cartilage.
  - The walls of the trachea and large bronchi contain incomplete rings of cartilage. Smaller bronchi have pieces of cartilage of irregular shape in their walls.
  - Parts of the nasal septum and the lateral wall of the nose are made up of pieces of hyaline cartilage.
- In growing children long bones consist of a bony diaphysis (corresponding to the shaft) and of one or more bony epiphyses (corresponding to bone ends or projections).
- Each epiphysis is connected to the diaphysis by a plate of hyaline cartilage called the ***epiphyseal plate***. This plate is essential for bone growth.

Elastic Cartilage

Description

Elastic cartilage (or yellow brocartilage) is similar in many ways to hyaline cartilage.

The main difference between hyaline cartilage and elastic cartilage is that instead of collagen fibres, the matrix contains numerous elastic fibres that form a network. The fibres are difficult to see in haematoxylin and eosin stained sections, but they can be clearly visualised if special methods for staining elastic fibres are used (Fig. 6.1). The surface of elastic cartilage is covered by perichondrium.

Elastic cartilage possesses greater fiexibility than hyaline cartilage and readily recovers its shape after being deformed.

Distribution of Elastic Cartilage

- It forms the 'skeletal' basis of the ***auricle*** (or pinna) and of the ***lateral part of the external acoustic meatus***.
- The wall of the ***medial part of the auditory tube*** is made of elastic cartilage.
- The ***epiglottis*** and two small ***laryngeal cartilages*** (corniculate and cuneiform) consist of elastic cartilage. The apical part of the arytenoid cartilage contains elastic fibres but the major portion of it is hyaline.

Note that all the sites mentioned above are concerned either with the production or reception of sound.

Fibrocartilage

Description

On superficial examination this type of cartilage (also called ***white fibrocartilage***) looks very much like dense fibrous tissue. However, in sections it is seen to be cartilage because it contains typical cartilage cel s surrounded by capsules.

There is no perichondrium over the cartilage. This kind of cartilage has great tensile strength combined with considerable elasticity. The collagen in fibrocartilage is different from that in hyaline cartilage in that it is type I collagen (identical to that in connective tissue), and not type II. The fibrocartilage in contrast to hyaline cartilage does not undergo calcification.

Distribution of Fibrocartilage

- Fibrocartilage is most conspicuous in secondary cartilaginous joints or ***symphyses***. These include the joints between bodies of vertebrae (where the cartilage forms intervertebral discs); the pubic symphysis; and the manubriosternal joint.
- In some synovial joints the joint cavity is partially or completely subdivided by an ***articular disc***. These discs are made up of fibrocartilage (Examples are discs of the temporomandibular and sternoclavicular joints, and menisci of the knee joint).
- The ***glenoidal labrum*** of the shoulder joint and the ***acetabular labrum*** of the hip joint are made of fibrocartilage.
- In some situations where tendons run in deep grooves on bone, the grooves are lined by fibrocartilage. Fibrocartilage is often present where tendons are inserted into bone. (For further detail see Author Book- B Singh Histology)

BONES

Bone (or ***osseous tissue***) is a tissue of great strength and resilience. It is the hardest tissue of the body. It consists of cells, fibres and a matrix. The matrix is extracellular (outside the cells) and is calcified (has deposition of calcium salts). This calcification gives hardness and strength to the bone tissue. The presence of fibres gives some amount of elasticity.

Functions of Bones

Bones have several important functions that it is almost impossible to imagine the human body without bones. Bones, along with the joints, (Fig. 4.1) cartilage and some connective tissue, form a bony skeleton that accords a framework to the human form. The muscles, connective tissue and skin clothe this framework, ultimately leading to the familiar human appearance. Blood vessels and nerves go to different parts of the body in close proximity to the bones.

Various functions of bones and the bony skeleton can be listed as follows:

- ***Framework:*** Skeleton gives shape and form to the human body;
- ***Protection:*** Internal structures and organs are given protection by the various parts of the skeleton; cranium protects brain; thoracic cage protects the lungs and the heart;
- ***Leverage for muscle action:*** Skeletal muscles are attached to the bones and the bones act as levers for the muscles to contract;
- ***Storage:*** Bones are reservoirs of calcium salts;
- ***Blood formation:*** Within their cavities, bones have the blood forming bone marrow.

Architecture of Bone

Depending on the physical structure and appearance of the bone, two types of it are described, namely, the ***compact bone*** and the ***cancellous bone***. Bone substance forms ***trabeculae*** (small and thin plates of tissue; Greek. trabecule=little beams) and the types are based on the arrangement of these trabeculae.

- ***Compact bone:*** If we examine a longitudinal section across a bone (such as the humerus), we see that the wall of the shaft is tubular and encloses a large ***marrow cavity***. The wall of the tube is made up of a hard dense material that appears, on naked eye examination, to have a uniform smooth texture with no obvious spaces in it. This kind of bone is called ***compact bone***. Compact bone, also called ***dense bone***, the trabeculae are thick, closely packed and run almost in the same direction (giving a compact appearance).
- ***Cancellous bone (spongy bone):*** When we examine the end of long bone and diploë of flat bones we find that the marrow cavity does not extend into them. They are filled by a meshwork of tiny rods or plates of bone and contain numerous spaces, the whole appearance resembling that of a sponge. This kind of bone is called ***spongy*** or ***cancellous bone*** (cancel = cavity). The spongy bone at the bone ends is covered by a thin layer of compact bone, thus providing the bone ends with smooth surfaces (Fig. 4.2). Small bits of spongy bone are also present over the wall of the marrow cavity. In the cancellous or ***spongy bone***, trabeculae are thin and spread out in a meshwork (giving a spongy appearance) (Fig. 4.2).

All bones have an outer layer of compact bone. The interior of most bones is filled with cancellous bone. Also note all newly formed bones are cancellous bones. Later it is converted to compact bone. Where the bone ends take part in forming joints they are covered by a layer of articular cartilage. With the exception of the areas covered by articular cartilage, the entire outer surface of bone is covered by a membrane called the ***periosteum***. The wall of the marrow cavity is lined by a membrane called the ***endosteum***.

The marrow cavity and the spaces of spongy bone (present at the bone ends) are filled by a highly vascular tissue called ***bone marrow***. At the bone ends, the marrow is red in colour. Apart from blood vessels this ***red marrow*** contains numerous masses of blood forming cells (***haemopoietic tissue***). In the shaft of the bone of an adult, the marrow is yellow. This ***yellow marrow*** is made up predominantly of fat cells.

Classification of Bones (Fig. 4.3)

Bones are classified according to their general shapes and each category has its own predominant characteristics

- ***Long bones:*** Their length is greater than their breadth. These are found in the limbs. Examples are the humerus, femur, radius, tibia, metacarpals, metatarsals and the phalanges. The shaft has a central cavity called the medullary cavity (Greak.medullare=middle) that contains the bone marrow. The ends of a long bone are usually articular and so are covered by articular cartilage. The bone of the shaft is of the compact variety; the ends are composed of cancellous bone which is covered by a thin layer of compact bone.

PARTS OF LONG BONE (FIG. 4.4)

A young long bone consists of:

- Diaphysis
- Epiphysis
- Epiphyseal cartilage
- Metaphysis

Diaphysis

It is the part of bone which ossifies from the primary centre and forms the shaft of bone. It is composed of a thick collar of dense compact bone beneath which there is a thin layer of spongy trabecular bone enclosing the marrow cavity.

contd…

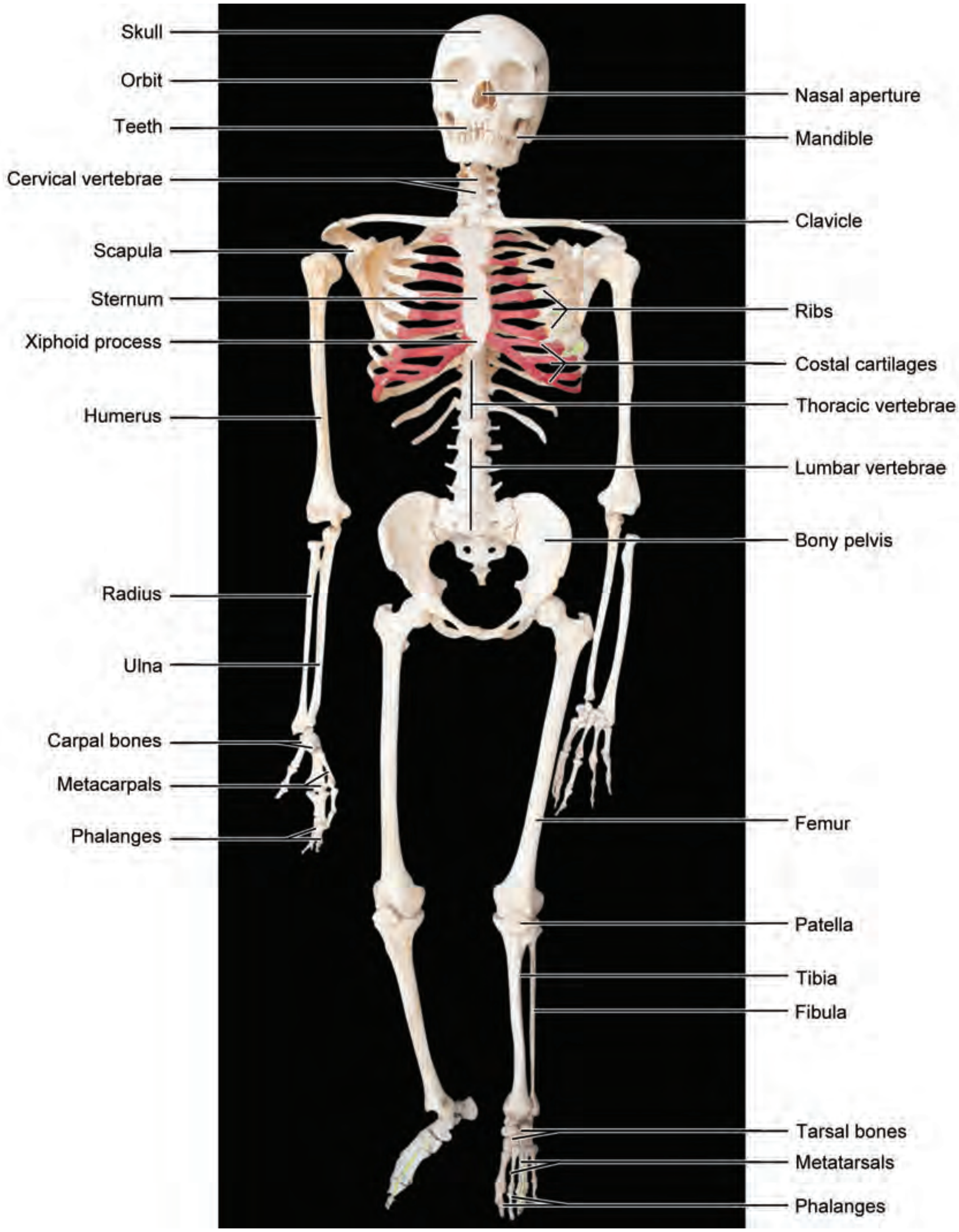


Fig. 4.1: Human skeleton

contd…

Epiphysis

It is the part of bone which ossifies from the secondary centres

Epiphyseal Cartilage

It is a plate of cartilage which intervenes between the epiphysis and diaphysis of a growing bone. Epiphyseal cartilage persists till the bone is growing. When the full length is achieved, epiphyseal cartilage is replaced by bone and further growth stops.

contd…

contd…

Metaphysis

The end of diaphysis adjacent the epiphyseal cartilage is known as ***metaphysis***. Characteristics of metaphysis are:

- It is the most actively growing area of long bone.
- Metaphysis has a rich blood supply derived from nutrient, periosteal and juxta-epiphyseal arteries. Nutrient arteries form pin head-like capillary loops in the metaphysis. Hence, any circulating microorganisms can settle in these loops Thus, infections of long bones primarily affect the metaphysis.

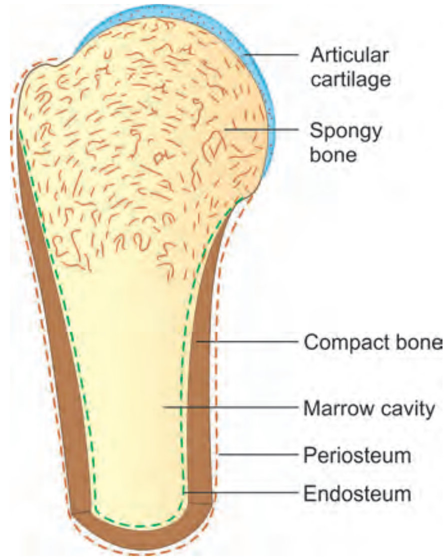


Fig. 4.2: Some features of bone structure as seen in a longitudinal section through one end of a long bone

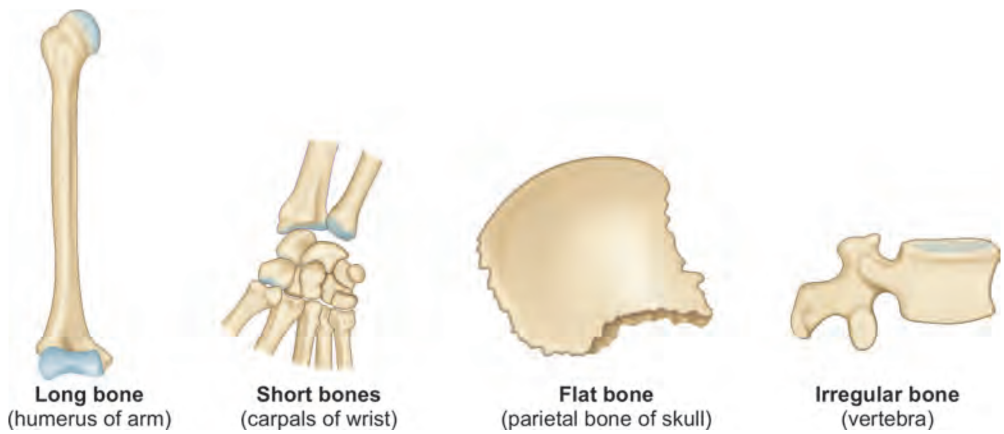


Fig. 4.3: Types of bones

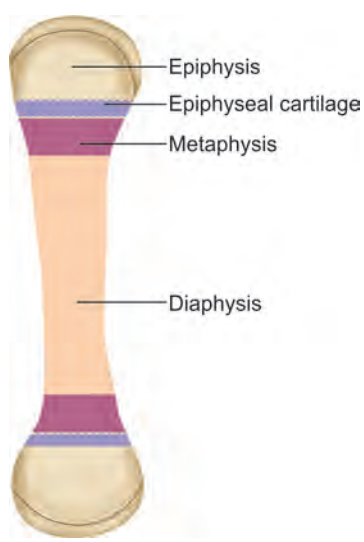


Fig. 4.4: Parts and features of a long bone

- ***Short bones:*** They are more or less cubical (or cuboidal) in shape and are found mainly in the hands and feet. Examples are the tarsal bones like the calcaneus and talus and the carpal bones like the scaphoid and lunate. They are predominantly composed of cancellous bone with a thin layer of compact bone surrounding it. Many short bones are covered by periosteum.
- ***Flat bones:*** They appear flat and are found in the skull. Examples are the frontal and parietal bones. There are two layers of compact bone, one inner and the other outer; these layers are called the ***tables***; between the tables is a layer of cancellous bone called the ***diploe***. The Scapula, which is the shoulder blade, though irregular in shape, is usually included in the group of flat bones.
- ***Irregular bones:*** Bones which do not fall into any of the above-mentioned categories are classified as irregular. Examples are the vertebrae, some bones of the skull and the pelvic bones They are made up of cancellous bone surrounded by a thin layer of compact bone.

Special Types of Bones

These are bones which either have a specialised cause for appearance or have a specialised modification of architecture. Two examples in the human body are the sesamoid bones and the pneumatic bones.

- ***Sesamoid bones:*** These are bones which develop in tendons, when the tendons rub against bony surfaces causing constant friction. They are seen and felt like small seeds and hence the name (Arabic. sesame=seed). As the bone develops, the surface of the bone that rubs against the ***original*** and ***larger*** bony surface becomes articular and is covered with articular cartilage. There is no periosteum. The largest sesamoid bone of the human body is the patella that occurs in the tendon of quadriceps femoris.
- ***Pneumatic bones:*** These are a part of a recapture of the situation in the birds. Many of the bones, in the birds, are invaded by air-sacs from the respiratory system, so as to make the body light in weight (to help in flying). In the humans, some of the skull bones are invaded by air-sacs from the nose. The spongy cancellous part of the bone is invaded by air cavities and so the walls of the outer compact bone get lined by mucous membrane. Through small openings in the bone, this mucous membrane is continuous with that which lines the nose and the nasal cavity; thus, the bones with air-sacs communicate permanently with the nose. These air sacs or air cavities are called the ***paranasal sinuses*** The air sinuses lighten the skull and provide resonance to voice. Since they are in contact with the nose and nasal cavity, infections of the latter can spread into them. Bones with such sinuses are the frontal, maxillary, sphenoid and ethmoid bones. Similar air cavities extend from the middle ear into the mastoid part of the temporal bone and are called the mastoid air cells.
- ***Accessory bones:*** These are bones which have developed from a centre of ossification but have failed to fuse with the main mass or have developed from an additional or abnormal centre of ossification. Examples are the sutural bones which occur in the sutures of the skull.

Bone Marrow

Bone marrow is present in the marrow cavity of the long bone. In many short bones too, there is a small marrow cavity. In the flat and irregular bones, it is present in the interstitial spaces of the cancellous bone. The marrow of all the bones is red and haematopoietic (producing blood cells) at birth. Blood producing capacity gradually decreases with age and slowly the red marrow is replaced by yellow marrow. This replacement first starts in the distal bones of the limbs just before the age of 10. As age advances, replacement spreads. When the individual is a mature adult, red marrow can be seen only in the bones of skull, upper part of the vertebral column, the girdle bones, the thoracic cage and the heads of humerus and femur (all these are cancellous bone). In the sternum, red marrow persists throughout life. Red and white blood cells are produced in the bone marrow; after birth, marrow is the only source of red blood cells. Active blood forming marrow is red in colour due to the red cells and hence, called the red marrow. Yellow marrow is mainly composed of fatty tissue (hence the yellow colour) with a few blood forming cells. Gelatinous marrow is the degenerate marrow found in the skull bones of very old people.

Periosteum

The external surface of any bone is, as a rule, covered by a membrane called periosteum.

Note: The only parts of the bone surface devoid of periosteum are those that are covered with articular cartilage.

Bone surfaces, excepting the articular surfaces are covered by a thick sheath of fibrous connective tissue called the periosteum (Greek.peri=around, osteon=bone). It can be described to have two layers; the ***outer fibrous layer*** (made up of densely packed fibres with some connective tissue cells) and an ***inner cellular*** and ***vascular layer***. The inner layer gives rise to bone forming cells called the osteoblasts, because of which the layer is dubbed the ***ost ogenic*** (osteo=bone,genic=forming) layer. The periosteum is closely adherent to the bone because of two factors. The first factor is that many of the fibres of the periosteum run into the bone, penetrate it and get incorporated into it. These are the ***Sharpey's fibres*** (Fig. 4.5). At the place where the tendons and ligaments are attached to the periosteum and the underlying bone, Sharpey's fibres are very dense The second factor is that blood vessels run from it to the bone to supply the bone substance and the marrow. Very often it is noted that if periosteum is stripped off a bone, blood supply to the said bone is lost and the underlying bone undergoes death. The inner layer of periosteum also has osteoclasts which are bone destroying cells.

Periosteum is richly supplied with somatic sensory nerves which carry pain fibres. This is the reason why fractures are extremely painful. Apart from providing protection and nutrition to the underlying bone, the periosteum helps in bone growth and bone repair.

The trabeculae of cancellous bone have a thin layer of connective tissue over them; this is the ***endosteum***. It can be described as the covering layer of internal bony surfaces. It also contains osteoblasts and osteoclasts.

Markings on a Bone

When fibrous t ssue is attached to a bone, markings are produced at the point of attachment. These markings are

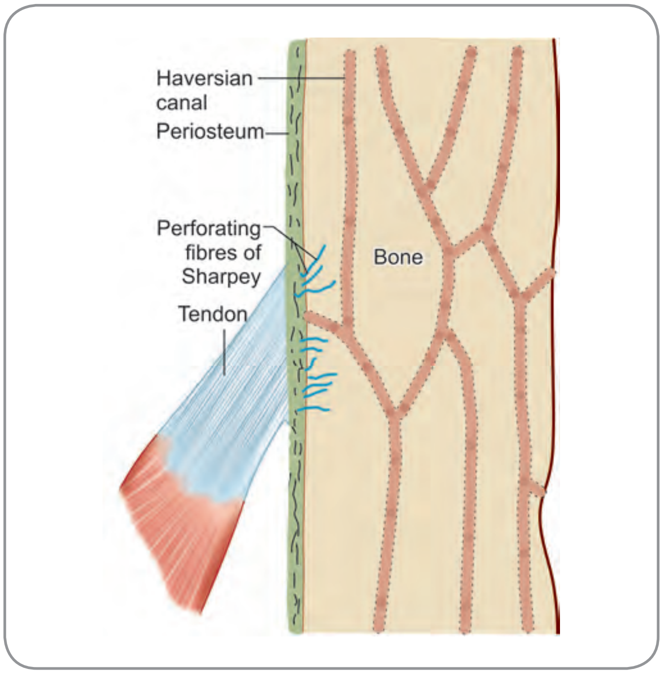


Fig. 4.5: Longitudinal section of compact bone

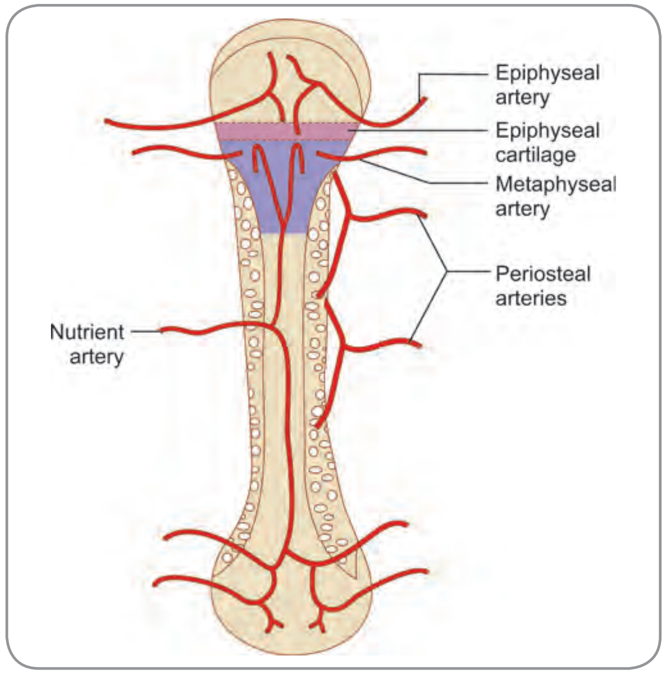


Fig. 4.6: Blood Supply to a Bone

not present at birth and in the young. They appear around puberty and are well seen in the adult bone.

> As the well cleaned and dried bones are taken up for study, these markings are prominent and are given various names to facilitate identification. Markings which are raised up from the surface are ***elevations***; a sharp elevation is called a ***spine***; linear elevations can be a ***line***, a ***ridge*** o a ***crest***; rounded elevations can be a ***tubercle***, a ***tuberosity***, a ***trochanter*** or a ***malleolus***. Markings which run lower to the surface are ***depressions***. A very small depression is called a ***pit*** or a ***fovea***. Large cup-like depression is a ***fossa***. Linear depression is a ***groove*** or a ***sulcus***. A depression in a border is a ***notch;*** and this notch may be bridged by a igament. A hole or opening is a ***foramen*** A tubular tunnel like structure is called a ***canal*** or a ***meatus***. The canal will have at both its ends, an opening called the ***orifice*** or ***ostium***. A large and prominent rounded area is called the ***head*** or ***capitulum*** (Latin.caput=head). Smaller rounded areas are called ***condyles***. Condyles often occur in pairs and near articular areas. A smaller eminence superior or adjacent to a condyle is an ***epicondyle***. A pulley shaped part is called a ***trochlea***.

When a blood vessel or a nerve runs through an ostium or orifice or notch or foramen, the underlying bony surface becomes smooth and rounded. It is possible to see such markings in a dry bone and the direction of the vessel or nerve can be determined.

Blood Supply to a Bone (Fig. 4.6)

Bone is a living tissue and hence requires constant blood supply. A bone receives supply from several arteries in the periosteum and in the case of a long bone, from a large ***nutrient artery*** that enters the shaft through a ***nutrient foramen***. As more and more bone is formed and laid at the growing end of a bone, its ***nutrient canal*** and artery are gradually rendered oblique and are directed away from the growing end (which is also called the epiphyseal end). In bones where both ends are growing, the nutrient canal is directed away from the more actively growing end. It is seen that the shoulder end of humerus and the wrist ends of radius and ulna grow more than the elbow ends; so elbow is less growing in nature. In the lower limb, knee ends of both femur and tibia grow more than the hip and ankle ends respectively; so the knee is more growing in nature. The nutrient canals in the long bones of upper limb and lower limb, thus are described with a statement—***'to the elbow I go, from the knee I flee'***.

The typical blood supply to a long bone can be stated to be as follows (Fig. 4.6):

- ***Periosteal branches:*** They enter the shaft at multiple points and supply the compact bone;
- ***Nutrient artery:*** They are the medullary artery–enters the medullary cavity through the nutrient canal and divides into a proximal and distal branch; each of these gives out several branches which supply the marrow, the compact bone and the metaphyseal area. The nutrient artery is the main artery of the shaft;
- ***Branches from adjacent articular arteries:*** They Arteries which anastomose around joint give out smaller twigs; these twigs are the epiphyseal twigs and metaphyseal twigs and supply to the concerned region.

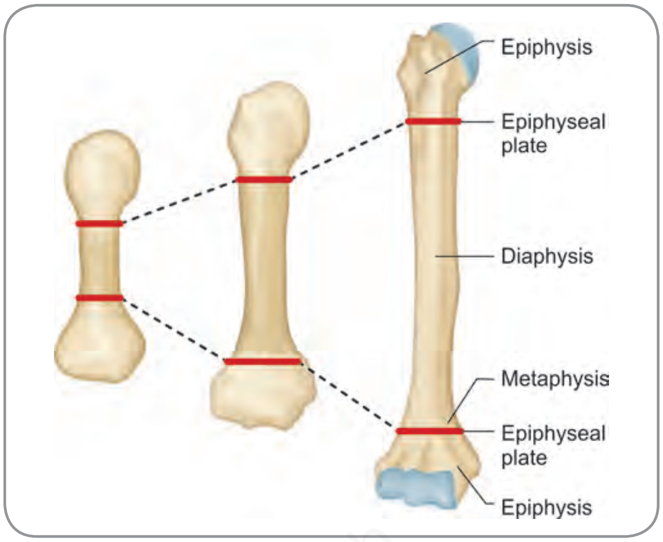


Fig. 4.7: Development and ossification of a long bone

Ossification

Ossification is a process by which bone is formed. All bones are mesodermal in origin. Bone is not straightaway formed in the body but is developed in cartilage or in membrane Depending on this, there are two types of ossification, namely, the cartilaginous ossification and the membranous ossification (Fig. 4.7). The bones formed by endochondral ossification are called ***chondral bones*** where as bones formed by membranous ossification are called ***membrane bones***. The bones of the vault of the skull, the mandible, and the clavicle are membrane bones.

Cartilaginous Ossification (Enchondral or Endochondral Ossification)

It can be well studied in long bones. The future bone, before ossification, is in the form of a cartilaginous rod. The process of ossification starts in the centre of the shaft region by about the 7th to 11th week of intrauterine life of the embryo. This centre is called the ***primary centre of ossification***. Ossification proceeds both proximally and d stally and thus the shaft is formed from the primary centre. The ends are formed from centres of ossification which appear later in those areas; since these centres appear later than the 'first' centre and contribute to only additional parts of the bone, these are called the ***secondary centres***. Except for a few, the secondary centres appear after birth and continue to appear till around puberty.

The process can further be understood by imagining a typical long bone The cartilaginous shaft becomes a bony rod from the primary centre. Secondary centres make their appearance in the upper and lower ends, one in each. From a small central zone, ossification proceeds around and both the ends therefore become bony masses. If, at this point, the bony rod and the bony masses of the two ends fuse (by completing ossification), the bone can no longer grow; it cannot ncrease in length and in size. To allow the bones to grow and reach lengths in such a way that the individual attains his/her adult height, fusion between the derivatives of primary centre (diaphysis) and the secondary centres (bony epiphysis) are delayed. It should be remembered that the bone to be formed is already a cartilaginous model. As the individual grows, ossification keeps progressing in the primary and secondary centres until only two areas of cartilage are left out. These are the (a) the piece of cartilage that covers the end of the bone forming the articular cartilage and (b) the plate of cartilage that remains between the diaphysis and the bony epiphysis. The latter is called the ***epiphyseal plate***. When the bone has attained its adult length, the epiphyseal plate is also ossified and the entire bone becomes completely osseous. This is called ***epiphyseal closure*** or ***epiphyseal fusion***. Once epiphyseal closure occurs, the bone cannot lengthen any further at that area.

The ***law of ossification*** guides the process. The law states that the secondary centre which appears first will fuse the last. A typical example can be seen in the tibia. The primary centre appears by the seventh week of intrauterine life. Ossification spreads up and down so that at birth only the ends remain cartilaginous. The secondary centre for the upper end appears at birth and the one for the lower end appears by the end of first year of age. Fusion at the lower end occurs between 16 and 18 years and at the upper end between 17 and 19 years. Fibula is an exception to the law

The part of diaphysis adjacent to the epiphyseal cartilage is called the ***metaphysis***. This is the area where growth in length of a bone is taking place (Greek. meta=beyond, physis=growth).

Process of Ossification

Further details of the process of ossification can be studied with a cartilage model. Let us say, a future long bone now is in the form of a cartilaginous rod (Fig. 4.8).

- ***Step 1***: The perichondrium of the cartilaginous rod becomes periosteum; osteoblasts (bone forming cells) in the periosteum start depositing bone tissue around the cartilage rod.
- ***Step 2***: In the middle of the rod, cartilage cells enlarge; immediately around these enlarged cells, the matrix starts calcifying. Because of calcification, nutrients cannot diffuse and so the trapped cartilage cells disintegrate and die. Small cavities appear in the central region. In the rest of the rod, cartilage cells continue to grow, thus making the rod longer.
- ***Step 3***: A small bud of tissue from the periosteum, containing small vessels projects into the cavities in the central areas This periosteal bud also has osteoblastic

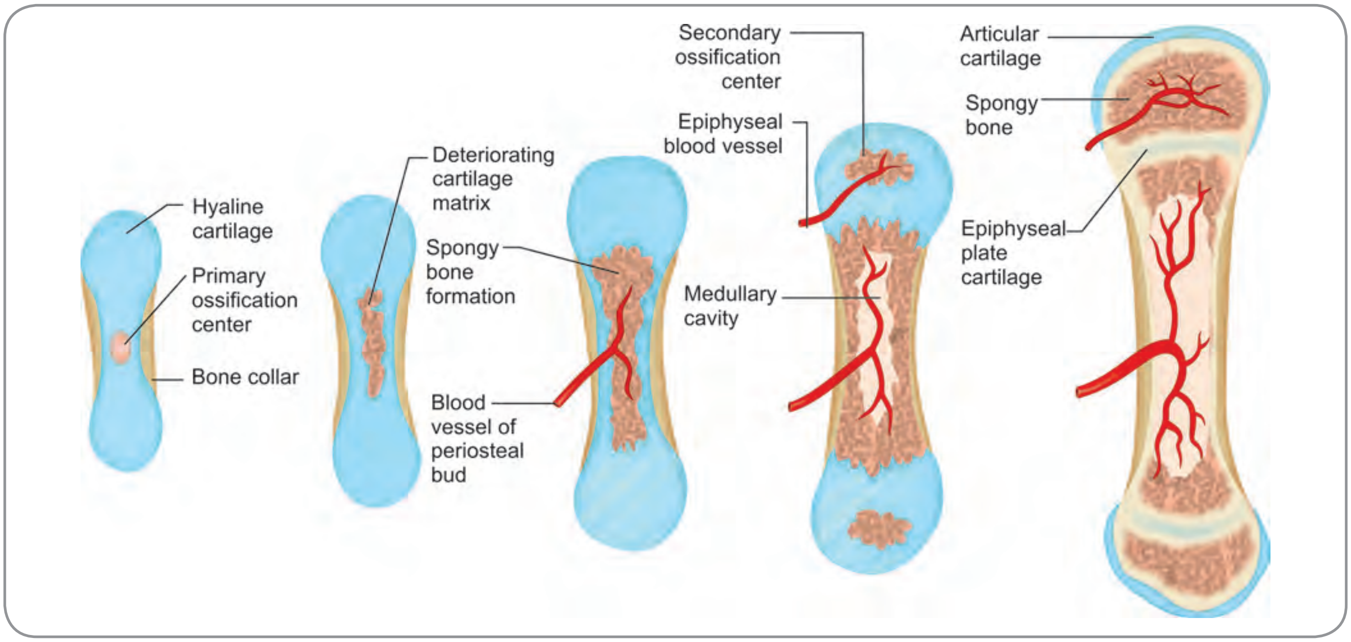


Fig. 4.8: Stages of ossification

and osteoclastic cells. Osteoblasts form bone tissue around zones of calcified matrix. Thus, the first trabeculae start appearing. This will also be the beginning of spongy bone. Bone tissue that appears in the central region will go to form the primary ossification centre

- ***Step 4***: Changes take place in the epiphyseal region of the rod. In the part close to the diaphyseal region, the cartilage cells get arranged one over the other, in long columns. The cells close to the free edge of the rod multiply rapidly. This causes increase in length. At the same time, the diaphysis and epiphysis get separated away.
- ***Step 5***: The older cartilage cells closer to the diaphysis in the column, signal for calcification. As the surrounding area gets calcified, these cells disintegrate. So thin projections of calcified cartilage stick out. Bone is formed around these projections. But more in the centre, formed bone is also reabsorbed thus creating a medullary cavity.
- ***Step 6***: Meanwhile, bone continues to be formed around the periphery of the rod.
- ***Step 7***: Changes at the epiphyseal region. These changes are similar to those which happen in the diaphyseal centre earlier. The cartilage cells in the centre of the said epiphyseal area induce calcification; as a consequence of surrounding calcification, they degenerate. A small bud of tissue with vessels invades in; bone trabeculae appear. This then becomes the secondary centre of ossification
- ***Step 8***: Depending upon the length and shape of the bone, more secondary centres appear.
- ***Step 9***: Once all secondary centres have appeared and the primary diaphyseal area is also being ossified, the original cartilaginous rod is now almost completely replaced by bone tissue except for in two places—(1) On the epiphyseal surfaces or the surfaces of the ends, where the left out cartilage will become the articular cartilage; and (2) between the diaphysis and epiphysis, where it forms the epiphyseal plate (also called the growth plate or epiphyseal d sc).
- ***Step 10***: As the epiphyseal plate remains cartilaginous, growth continues. Cartilage cells of the epiphyseal plate on the diaphyseal side keep dividing and thus the diaphyseal side keeps lengthening. Enlargement of these cells, calcification and bone formation proceed to happen. Thus, lengthening of the cartilage rod and its ossification occur.
- ***Step 11***: When the bone is no longer required to grow further, the cartilage cells in the epiphyseal plate divide less and the plates become thinner. Slowly they are replaced by bone tissue. Bony regions of diaphysis and epiphysis fuse. This is the process of closure of epiphyseal plates. After this, the bone cannot increase in length.

Development

Time Tables of Events

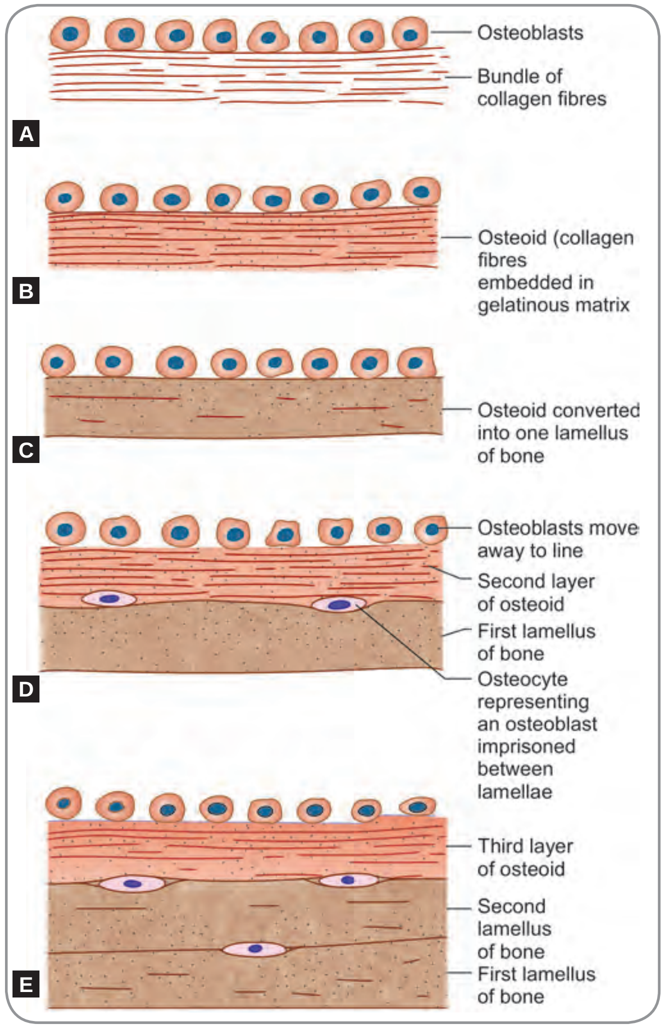
- ***Steps 1 to 3:*** These steps occur in the embryo; By the tenth to twelfth week of intrauterine life, bone tissue has appeared in the diaphyseal centre and also around it. Most primary ossification centres make their appearance by the seventh to eighth week of intrauterine life.
- ***Steps 4 to 6:*** These happen in the developing foetus.
- ***Step 7:*** This occurs just before or soon after birth.
- ***Steps 8 to 10:*** These changes continue to happen in the growing child and during adolescence.
- ***Step 11:*** This happens around 18 to 21 years of age after which the ind vidual can no longer grow taller.

Membranous Ossification (Intramembranous Ossification)

Bone is formed in a fibrous membrane without the intervention of cartilage.

The various stages in intramembranous ossification are as follows:

- At the site where a membrane bone is to be formed the mesenchymal cells become densely packed (i.e. a ***mesenchymal condensation*** is formed).
- The region becomes highly vascular.
- Some of the mesenchymal cells lay down bundles of collagen fibres in the mesenchymal condensation. In this way a membrane is formed.
- Some mesenchymal cells (possibly those that had earlier laid down the collagen fibres) enlarge and acquire a basophilic cytoplasm, and may now be called osteoblasts (Fig. 4.9A).
- They come to lie along the bundles of collagen fibres. These cells secrete a gelatinous matrix in which the fibres get embedded. The fibres also swell up. Hence the fibres can no longer be seen distinctly. This mass of swollen fibres and matrix is called ***osteoid*** (Fig. 4.9B).
- Under the influence of osteoblasts calcium salts are deposited in the osteoid. The osteoblasts which are now surrounded by matrix are called osteocytes
- This new bone tissue is forming around a network of embryonic blood vessels. So the bone trabeculae also run in a network and the woven bone tissue is formed. In this stage, the embryonic spongy bone does not have lamellae.
- In this stage, mesenchyme which is just external to the developing membrane bone condenses to form the periosteum.
- Subsequently, the trabeculae at the periphery grow thicker. A few layers of osteoid are laid down (Fig 4.9C and D); each layer undergoes steps of mineralisation. Once mineralised, the osteoid layer is called a lamella. Few lamellae are thus formed.
- In the central area of the membrane bone, the trabeculae remain as such and form the spongy bone.
- The membrane bone, after all these steps, has outer layers of compact bone which sandwich a central cone of spongy bone (diploe in the skull bones). A thick periosteum covers the outer surface of the compact bone and a thin endosteum lines the spongy bone.



Figs 4.9A to E: Scheme to show how bony lamellae are laid down over one another

Epiphysis

It is the part of a bone, usually at the ends, that has developed from a separate centre of ossification. Depending upon the cause of appearance, epiphysis (plural, epiphyses) can be of the following types:

- ***Pressure epiphysis***: This occurs at the end which is articular. The constant pressure at this end, due to rubbing with the other bone of the joint and also due to frequent movements, causes ossification to start; the epiphysis is thus formed. Examples are the secondary centres at the ends of the long bones of the limbs, especially the humerus, radius, femur, tibia and fibula.
- ***Traction epiphysis***: This appears because of the traction effect produced by the attachment of a tendon on the bone. The traction pull causes ossification to set in and the centre usually appears around puberty. Examples are the centres for the tubercles of humerus and the trochanters of the femur.
- ***Atavistic epiphysis***: Some bones which are separate in the lower animals have got attached to other bones in the humans. These attached pieces ossify by a separate centre and forms the atavistic epiphysis. Example is the coracoid process of the scapula.

Added Information

- Bones have an organic framework made up of cells and fibrous tissue; the inorganic salts are deposited within it. One-th rd is organic and two-thirds are inorganic.
- ***Constant remodelling*** occurs in bone tissue to make it withstand strains and stresses. The bone that is not required (either redundant bone or bone made useless) is reabsorbed. Examples can be seen when a tooth is extracted and when a limb is paralysed. The bony walls of the socket which are now redundant and the bones of the limb which now have no proper function (since muscles do not work) are resorbed; the former disappear and the latter atrophy. On the contrary, when a bone has to support more weight, it hypertrophies.
- The bony trabeculae withstand compression and tensile forces. Where such forces are greater, the trabeculae crisscross, form a network, arch over and spread out so as to function efficiently. Examples are the upper end of femur and the calcaneum. In the upper end of femur, the trabeculae run out of the compact bone, diverge, arch over and reach the head and greater trochanter. This gives resilience and strength. In the central part of the calcaneum, the trabeculae are spread out and this factor aids in weight bearing.
- In the shaft region of long bones, a transitional zone of coarse cancellous bone is usually seen between the compact bone and the medullary cavity.
- The shaft of a long bone is so designed to be hollow so that there is more strength with less material and less weight.
- Clavicle and ribs which are classified as long bones do not have medullary cavity.
- The flat bones have only a single plate at birth; the cancellous diploe along with its marrow makes appearance a few years later and splits the single plate into two.
- ***Accessory bones*** can occur in many places. Non failure with the main mass leads to accessory bones like interparietal piece of occipital squama, upper and lower pieces of zygomatic bone, acromial epiphysis of scapula, two pieces of lumbar vertebrae and bipartite patella. Supernumerary carpals and tarsals are examples of bones derived from additional centres of ossification.
- The frontal bone can remain in two pieces with a persistent ***metopic suture*** between the right and left halves.
- Sometimes bones form in soft tissues where they are not usually present. These are called ***heterotopic bones***. A typical example is a rider's bone which forms in the thigh in horse riders Friction over the thigh causes chronic muscle strain leading to small haemorrhages which eventually calcify and subsequently ossify.
- The anastomoses between the branches of nutrient artery of a bone and its periosteal branches are very meager. But there is considerable anastomoses between the metaphyseal twigs of articular branches and the metaphyseal branches of the nutrient artery. In fractures where the nutrient artery is torn, the supply is replenished by the articular branches.
- Venous drainage of a bone is effected by the periosteal and nutrient veins. However, major drainage is through the chief veins which run through large foramina near the ends of the bone. These veins drain into adjacent veins and carry the young blood cells from the marrow.
- Appearance of ***secondary centres of ossification*** is related to the amount of work done by the end of the bone. The end that has more work to do starts working earlier (starts ossifying earlier by the ear y appearance of secondary centre) and stops working later (fuses later).
- The original site of the epiphyseal cartilage is marked by the ***epiphyseal line*** in the completely ossified bone.
- ***Ossification*** starts earlier in females and is completed earlier by a difference of about 3 to 4 years.
- Both ends of a long bone are growing. The end with a faster rate of growth is called the ***growing end***.
- Since the appearance of secondary ossification centres is age related, the presence or absence of these centres help in determining the age of an individual.
- ***Changes in epiphyses can be classified into three periods:*** Secondary centres appear from birth to 5 years. Ossification spreads from these centres till 12 years in girls and 14 years in boys. Epiphyseal fusion occurs from 12 or 14 years to 25 years, after which growth ceases.
- Secondary centres for lower end of femur and upper end of tibia appear in the 9th month of foetal life. If one of these centres is present, the child can be said to be ***full term***
- ***Epiphyseal centre*** for medial end of clavicle appears around 18–20 years and fuses between 25 years and 30 years. So, a clavicle with an unfused medial epiphysis should be from a person between 18 and 30 years of age.
- Humerus, radius, femur, tibia and fibula have ***pressure epiphyses*** at both their ends.
- As a bone lengthens, it also has to widen. Growth by addition of bone tissue to the surfaces is called ***appositional growth***.
- Osteoblasts in the periosteum add bone tissue to the external surface of diaphysis; on the internal surface of the diaphyseal wall, osteoclasts in the endosteum removes bone. Both bone deposition and removal occur at the same rate; the circumference of the long bone expands and the bone enlarges in width.
- Gravitational and exercise forces help thicken bone.

Clinical Correlation

- When there is no mechanical stimulation or stress bone is lost. When patients are bedridden for a long time, their bones ***atrophy***.
- Under low-gravity conditions, there is no mechanical stress on the bones. Bone tissue is gradually lost under such circumstances. Outer space is a low-gravity situation; long missions in outer space is hindered by the factor of bone loss.

contd…

Clinical Correlation *contd...*

- ***Osteoporosis:*** This is a group of diseases, where bone re-absorption outpaces bone deposition. Affected bones are thinner and less dense. Loss of bone mass occurs and leads to fractures. Ageing causes osteoporosis. Factors which aggravate age related osteoporosis are insufficient exercise, diet that is poor in calcium and protein and long drawn immobilization.
- Post menopausal women are more prone to develop osteoporosis (Greek.osteon=bone, porosis=many openings or pores). The oestrogen hormone helps to maintain normal bone density. Decline in oestrogen levels after menopause predisposes to bone porosity.
- Lack of mineralisation of the bones leads to ***osteomalacia*** (Greek.malakia=softening) and Rickets. The osteoid matrix is present but there is no calcification of the matrix. So, the bones soften and weaken. When weight is put on the affected bone, it bends and deforms. Osteomalacia occurs in adults and rickets occurs in children. Since the bones are still growing in a child, deformities occur in many bones. Cranium and rib cage are worst affected. Vitamin D and calcium deficiency are the causative factors.
- Pregnancy causes transfer of calcium from the mother to the foetus. Repeated pregnancies can predispose to osteomalacia.
- Bacterial infection of bone and bone marrow is called ***osteomyelitis***. Infection enters a bone from surrounding tissues, through blood stream or through fractures.
- ***Osteosarcoma*** is bone cancer.
- ***Pagets disease:*** This is a disease where both bone deposition and reabsorption are in excess. As bone deposition occurs rap dly, the newly formed bone called the pagetic bone which is immature. Bones thicken irregularly and are weak. Marrow cavity gets filled with bone. Men about 40 years of age are affected.
- ***In X-ray pictures*** of long bones in some children, ***'lines of arrested growth*** can be seen. These are transverse planes of greater density caused by slower growth during illnesses.

Multiple Choice Questions

1. Resilience of cartilage is due to:
   a. A thick perichondrium
   b. Water shells in the matrix
   c. Its lack of vasculature
   d. Fibres in the ground substance

2. In compact bone:
   a. Trabeculae are thin
   b. Trabeculae form a meshwork
   c. Trabeculae run in same direction
   d. Trabeculae are absent

3. In a growing bone, epiphyseal cartilage separates:
   a. Diaphysis from epiphysis
   b. Diaphysis from metaphysis
   c. Epiphysis from articular cartilage
   d. Diaphysis from medullary cavity

4. The nutrient canal of a long bone:
   a. Is directed towards its actively growing end
   b. Is directed away from its actively growing end
   c. Becomes horizontal as age advances
   d. Is closed in old age

5. Bones forming in soft tissues where they are not normally present are:
   a. Sesamoid bones
   b. Heterotopic bones
   c. Accessory bones
   d. Membranous bones

ANSWERS

1. b **2.** c **3.** a **4.** b **5.** b

Clinical Problem-solving

Case Study 1: A space travel scientist, after about 10 months of stay in space on a research mission, felt his bones had weakened. He was given calcium supplements and special exercises which put mechanical stress on his bones.

- What was the reason for the weakness in his bones?
- What was the basis of treatment given to him?
- Is it correct to put stress on his bones when they are already weak?

Case Study 2: A 4 year-old girl had bow legs, distorted rib cage and varied deformities in her bones.

- What was the probable condition afflicting the girl?
- What are the causative factors for such a condition?
- What is the name of a similar condition occurring in adults?

(For solutions see Appendix).

Chapter 5

Joints

Frequently Asked Questions

- Discuss a typical synovial joint.
- Write notes on (a) Gomphoses, (b) Symphysis, (c) Syndesmosis, (d) Sutures, (e) Synovial membrane.
- Write a note on Hilton's law.
- What are Haversian pads?
- How are synovial joints classified?

A ***joint*** is a junction between two or more bones or cartilages. Some joints are merely bonds of union between different bones and do not allow movement. Joints of the skull (sutures) belong to this category. Some joints allow slight movement, while some others (like the shoulder joint) allow great freedom of movement. Study of joints is called '***arthrology'*** (Greek.arthron=joint) or ***'syndesmology'*** (Greek.syndesmo=fastening or joining). A joint can also be called an ***articulation*** (Latin.articulatio=connecting) or an ***articulus***

CLASSIFICATION OF JOINTS

Classification by Movements

Joints essentially are anatomical entities which allow movements to occur. Hence, they can be classified according to the range of mobility.

- ***Immobile joint or synarthrosis:*** A joint where there is no movement; examples are the sutures of the skull.
- ***Partially mobile joint or amphiarthrosis*** (Greek. amphi=two): A joint where there is limited movement; examples are the intervertebral discs; the joint is called two-sided (amphi) because it is neither completely immobile nor completely mobile.
- ***Freely mobile joint or diarthrosis:*** (Greek.di=two). A joint where there is a wide range of movement; examples are the shoulder, hip and knee joints. The name 'diarthrosis' is frequently applied to the synovial type of joint, where the movements are free and the participating bones are separated from each other, qualifying the adjective 'two'

This classification is incomplete since joints which are classified as immobile also have some amount of mobility.

Classification by Number of Bones

Joints are, by definition, junctions of two or more bones. They can, therefore, be classified according to the number of articulating bones.

- ***Simple joint:*** A joint where two bones articulate.
- ***Compound joint:*** A joint where more than two bones articulate within a single capsule; examples are the wrist and elbow.
- ***Complex joint:*** A joint where the joint cavity is completely or partially divided; examples are the temporomandibular and the knee joints.

Note: When the skeletal elements are connected to each other by contiguous tissue, the movement possible in such a joint is minimal or nil. When the skeletal elements are connected by structures in such a way that a space or cavity exists between the bones, then the movement possible is wide and free.

Classification by the Intervening Continuity

Joints can also be classified by the continuity of tissue intervening between the bones.

- ***Contiguous joint:*** Where the bones are connected by compact and contiguous tissue; this is otherwise called ***a fusion joint*** or ***synarthrosis*** (Greek.syn=together; arthros=joint).
- ***Interrupted joint:*** Where the intervening tissue has spaces or cavities or gaps; this is otherwise called ***diarthrosis***.

- ***Transitional joint:*** Where the intervening tissue has a small gap that cannot be called a true cavity; this is also called ***hemiarthrosis*** or ***amphiarthrosis***.

Classification by Known Examples

An easy but superficial way of classifying joints is to call them by well-known examples.

- ***Skull type:*** Where the joints have no mobility and the joint itself is temporary.
- ***Vertebral type:*** Where the joints have limited mobility but are very secure and stable.
- ***Limb type:*** Where the joints are mobile but are not very secure on account of such mobility; they have intervening synovial tissue.

Classification by the Intervening Tissue

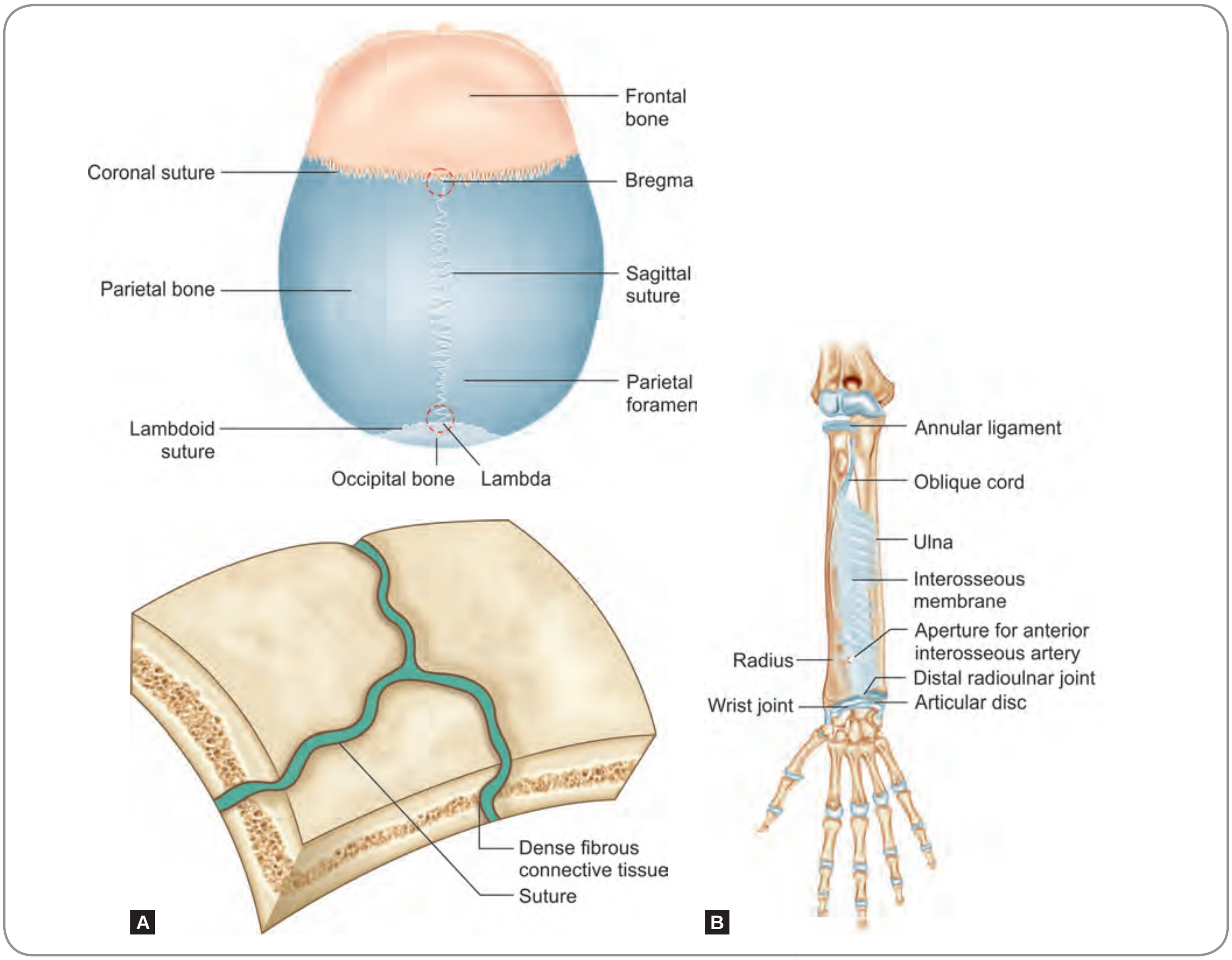
It can well be seen that the above given classifications are incomplete. The best way to classify joints will be on the basis of the intervening tissue.

- ***Fibrous joint:*** Where the intervening tissue between bones is fibrous (Fig. 5.1).
- ***Cartilaginous joint:*** Where the intervening tissue is cartilaginous (Fig. 5.2).
- ***Synovial joint:*** Where a cavity exists between the bones and synovial membrane lines this cavity (Fig. 5.1).

Fibrous Joints

The intervening tissue between the articulating (connecting) bones is fibrous in nature. Fibrous joints are subclassified into three types—(1) sutures, (2) gomphosis, and (3) syndesmosis.

- ***Sutures joints:*** (Latin.Sutura, derived from suo = a sewing or a seam). This is a type of joint found only in the skull and there is no active movement (Fig. 5.1A). The periosteal layers on the outer and inner surfaces of the articulating bones fill the gap between them and also constitute the main bond of the joint. Thus, fibrous tissue (periosteal fibrous tissue) intervenes between the articulating bones



Figs 5.1A and B: Types of fibrous joints **A.** Suture **B** Syndesmosis

and the joint is fibrous. A few small vessels are also present in the middle of the fibrous tissue. The fibrous mass between the two bones is called the sutural ligament. Active bone growth occurs at the sutural margins. Sutures are not permanent structures because of this growth. As the bony margins of the articulating bones grow towards each other, the fibrous tissue is replaced by bony tissue and the suture is thus obliterated.

Obliteration of suture leads to union of the articulating bones by bone tissue itself and this is called synostosis (syn+osteo=joining by bone). When a suture obliterates, ***synostosis*** occurs first on the deeper aspect of the suture (internal or endocranial aspect) and gradually extends to the superficial (external or pericranial) aspect. Complete obliteration occurs much later in life.

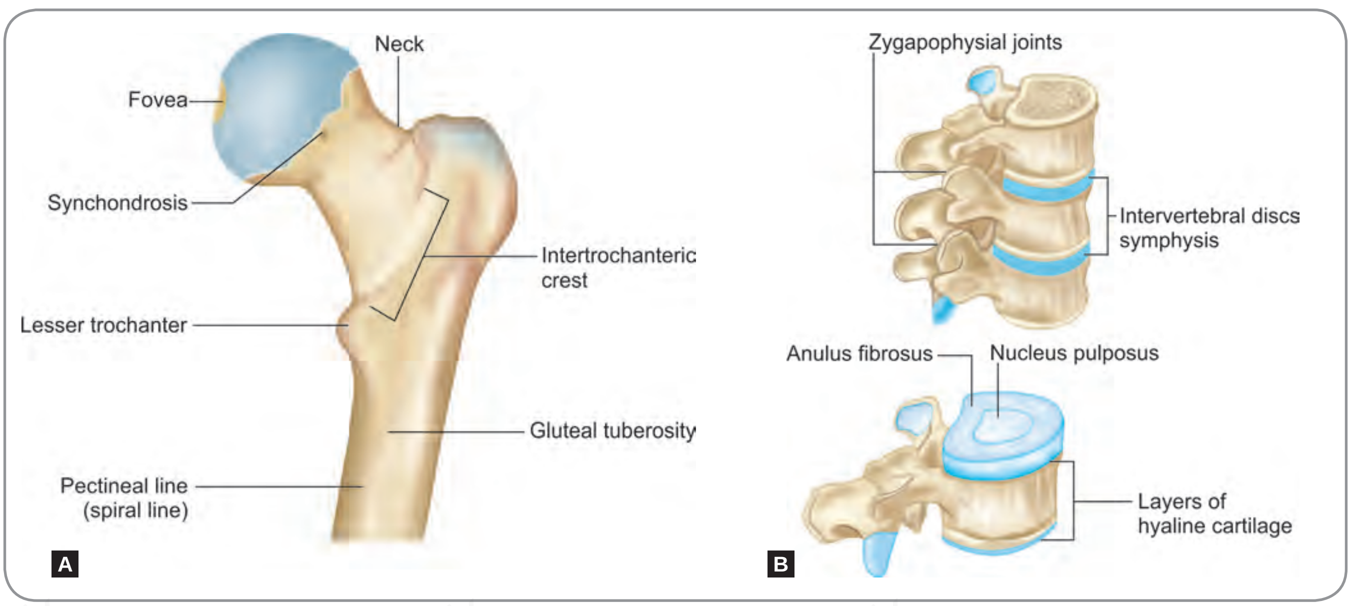
Sutures can be of many types depending upon the shape and form of the opposing edges.

- When the opposing edges do not show marked ruggedness and appear almost plane, it is a ***plane suture; example*** is the joint between the horizontal plates of the two palatine bones;
- When projections of one bone fit in the gaps produced by the projections of the opposing bone and the projections are sloping, it is a ***serrate suture; example*** is the sagittal suture between the two parietal bones;
- When the projections are rectangular it is ***dentate suture;***
- When the edge of one bone overlaps the edge of the opposing bone, it is a ***squamous suture; example*** is the suture between the parietal bone and the squamous plate of temporal bone;
- When the opposing edges are shaped like a wedge and its groove, it is a ***schindylesis*** (Greek. schindylez=splintering); the only ***example*** is the joint between the vomer and rostrum of sphenoid

- ***Gomphosis (plural, gomphoses)***: peg-in-socket joint or gompholic (Greek.gomphon=bolt) joint. This is a type of joint where one of the articulating partners is in the form of a peg which fits into a socket (the other articulating partner). ***Examples*** are the roots of teeth; the roots form the pegs which fit into the sockets in the maxillae and mandible.
- ***Syndesmosis (plural, syndesmoses):*** This is a type of joint where the intervening fibrous tissue is greater in amount than in a suture and the fibrous tissue forms an ***interosseous ligament*** or an ***interosseous membrane***. ***Examples*** are the:
  - Inferior tibiofibular syndesmosis, where the bones of tibia and fibula are joined by an interosseous ligament;
  - Joints between the shafts of the ulna and the radius in the forearm and the shafts of the tibia and the fibula in the leg; in both the places, the interosseous membrane intervenes and forms the union (Fig. 5.1B);
  - Joint between the coracoid process of the scapula and the clavicle where the coracoclavicular ligament intervenes.

When it is an interosseous ligament, the movement possible in the joint is due to the flexibility of the ligament. In the case of an interosseous membrane, movement is due to stretching and spiralling of the membrane.

  - ***Vertebral syndesmosis:*** Two vertebrae, one below the other, articulate with each other by their bodies, by their laminae, by their spinous processes and by their articular processes. The lamina of the upper



Figs 5.2A and B: Types of cartilaginous joints **A.** Synchondrosis (primary cartilaginous joint) **B.** Symphysis (secondary cartilaginous joint)

vertebra is united with the lamina of the lower vertebra by a fibrous band called the ***ligamentum flavum***. Since the ligamenta flava are made up of elastic fibres, they permit considerable movement (during bending and flexing of the vertebral column).

Cartilaginous Joints (Fig. 5.2)

The intervening tissue between the articulating bones is cartilaginous. Two types of cartilaginous joints are seen, namely the primary cartilaginous joint and the secondary cartilaginous joint.

- ***Primary cartilaginous joint:*** This is a type of joint where the intervening tissue is ***hyaline cartilage***; the cartilage remains cartilaginous as long as the joint exists. It is otherwise called the ***synchondrosis*** (Greek. syn=together, chondron=cartilage). The commonest ***example*** is the joint between the diaphysis and the epiphysis of a long bone. The epiphyseal cartilage is hyaline and intervenes (epiphyseal synchondrosis) between the two. The cartilage remains so until fusion occurs between the two (when fusion occurs, bone replaces the cartilage and the synchondrosis is converted to a synostosis).
  Another example of importance is the basisphenoid-basiocciput joint (spheno-occipital synchondrosis).
- ***Secondary cartilaginous joint:*** This is a type of joint where the intervening tissue is ***fibrocartilage***. It is otherwise called the ***symphysis*** (Greek.sym=together, phyez=growing; symphysis=growing together). The two articulating bones are united by fibrocartilage. A thin plate of hyaline cartilage is present between the fibrocartilage and the bone on both sides. Ligaments unite the articulating bones in front and behind and there is no joint cavity. However, a small cleft may be present.
  Usually symphyses (singular, symphysis) are found in the midline. ***Examples*** are the pubic symphysis (joint between the two pubic bones), manubriosternal symphysis (joint between the manubrium and the body of sternum) and the intervertebral symphyses (joints between the bodies of adjacent vertebrae with intervening intervertebral discs).

Synovial Joints (Fig. 5.3)

The intervening tissue between the articulating bones is the synovial membrane (synovial=joint egg) and synovial fluid. The bones are separated by a cavity that permits a good range of movements. The synovial joint can thus be described as a specialised and evolved class of joints so designed for the purpose of free movements. Since the limbs are primarily concerned with movements, most of the limb joints are synovial.

Features of a Typical Synovial Joint

A typical synovial joint exhibits the following characteristic features which form part of the synovial system.

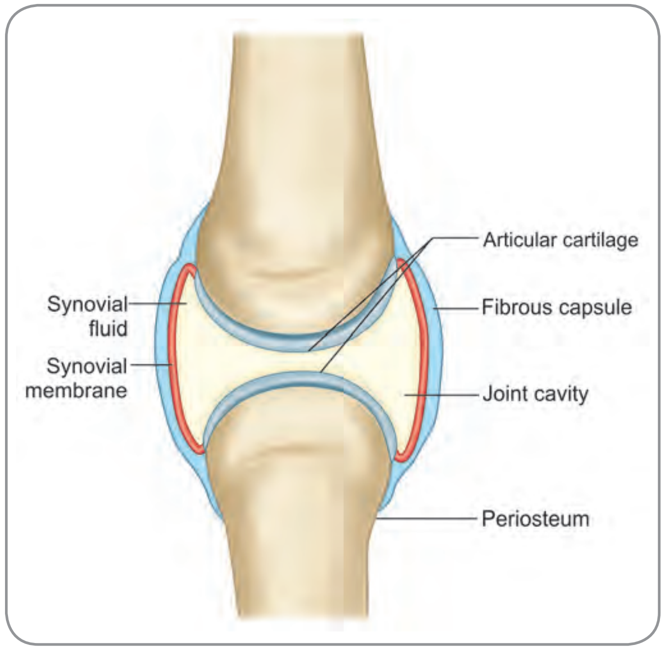


Fig. 5.3: Synovial joint

A synovial joint has:
- A joint cavity covered by capsule;
- An articular cart lage;
- An articular capsule, lined internally by a synovial membrane.

- ***Capsule and cavity:*** The articulating bones are connected by a sleeve of fibrous tissue called the capsule (joint capsule or fibrous capsule or articular capsule or membrane fibrosa) of the joint; because of the capsule, the articulating bones are placed at considerable distance from each other, thus giving freedom of movement. The capsule has a cavity on the internal aspect called the ***joint cavity*** or ***articular cavity***. The capsule itself is made up of densely packed collagen fibres; it is flexible enough to permit movement at the joint but also strong to resist any dislocation of the enclosed bones. The capsule can well be imagined to be a sleeve; each end of the sleeve is attached in a continuous line around the articular end of one of the participating bones. Where there are more than two bones in a joint, the capsule is accordingly irregular in shape. Small openings are seen in the capsule for nerves and vessels to pass through. There may be larger openings for synovial pouches to protrude.
- ***Articular cartilage:*** The ends of the articulating bones, where they actually come in contact with ('articulate' with) the opposing bone, are covered with hyaline cartilage; these form the articular cartilages. The articular cartilage is smooth and devoid of perichondrium. It is compressible and acts like a sponge, filling with the synovial fluid when free and squeezing the fluid out

when compressed. The articular cartilage derives its nutrition from three sources, i.e. from synovial fluid, from the vascular network present in the synovial membrane at the periphery of the cartilage and from the vasculature in the underlying bone.

- ***Accessory ligaments:*** The articulating bones are also united to each other by ligaments which stand apart from the capsule. These ligaments can be extracapsular (outside the capsule) or intracapsular (inside the capsule). Somet mes, parts of the fibrous capsule itself may be thickened and appear as ligaments. These form the intrinsic or capsular ligaments.
- ***Synovial membrane and fluid:*** The presence of synovial membrane (also called membrana synovialis) is the most characteristic feature of a synovial joint. The synovial membrane is a thin but highly vascularised layer that lines the internal aspect of the fibrous capsule (some authors prefer to call the two together as the articular capsule). From the interior of the capsule, the membrane is reflected onto the bony surfaces until the margin of the articular surface. The membrane also covers all the non-articular parts within the joint cavity. All non articular intracapsular structures are extrasynovial (they are inside the fibrous capsule but are excluded from the joint cavity by the folding of the synovial membrane). The synovial membrane secretes the synovial fluid, which is clear and slightly viscous. The name 'synovium' (Greek.syn=together, oon=egg; synovial=egg=like) itself is derived from the nature of this fluid resembling egg white. The fluid is, in normal life, just enough to form a thin film over all the surfaces within the joint and contains hyaluronic acid. It provides lubrication and gives nutrition to the articular cartilage. The cells in the synovial membrane migrate out into the fluid, remove micro-organisms and debris inside the cavity and re-enter the membrane, thus performing a cleansing action. Synovial fluid is also called ***'joint oil'***.
- ***Bursae:*** Around a joint, specially where muscle tendons rub against bony surfaces, small synovial sacs intervene between the rubbing structures. These are the bursae (singular, bursa).
- ***Articular disc:*** In some joints, a fibrocartilaginous disc extends internally from the capsule and subdivides the joint completely or partially. Such a disc is the articular disc or meniscus (Greek.meniskos=crescent). The articular discs improve the fit between the two articulating surfaces. In some joints, they permit two different movements—one movement on each face of the disc. Example of a joint that has a complete articular disc is the temporomandibular (jaw) joint Example where a partial disc is present is the knee joint, where the disc is shaped like a crescent, befitting the name 'meniscus'.
- ***Fat pads:*** Also called Haversian pads or glands. Pads of fat are seen between the synovial membrane and the fibrous capsule or between the membrane and bone. These pads usually project into the joint cavity but are covered by the synovial membrane. The fat, as it projects into the cavity, also pushes a fold of synovium. These folds, seen in all age groups, act as buffers during varying movements.

Neurovascular Supply to a Synovial Joint

Branches of the arteries of the region in which a joint is located freely give out branches to supply the joint. These branches penetrate the fibrous capsule and form a rich capillary plexus within the synovial membrane. Venous return is by a similar path from the capillaries to veins in the surrounding area. Lymphatics form a plexus in the synovial membrane and the efferent vessels pass to the flexor aspect of the joint. The fibrous capsule and, to a lesser extent, the synovial membrane, are supplied by nerve twigs which arise from the nerves of the region.

> ***Hilton's Law:*** This law, stated by John Hilton in 1863, relates to the nerve supply of a joint. 'The nerves which supply the muscles moving a joint also furnish branches to supply the joint and also the skin covering the joint and the distal attachments of the muscles.'

Functioning of a Synovial Joint

The synovial system is an elaborate lubricating system that permits the articulating bones to move against each other with minimal or no friction. If there was no lubrication, the bones would rub against each other, suffer damage and eventually the joint would lose its function. During various movements, the opposing bones in a joint are pulled towards one another. Their articular cartilages touch each other and are compressed. This squeezes the synovial fluid out of the cartilages and the fluid spreads as a thin film over the surfaces of the cartilages. As the two articular cartilages move, they move on the film and not on each other. When the movement is stopped and the pressure on the joint ceases, the articular cartilages reabsorb the synovial fluid, which is ready to be squeezed out the next time pressure occurs. This mechanism is called ***weeping lubrication***.

Factors Maintaining Joint Stability

Joint stability in a synovial joint depends on the integrity of union between the articulating bones. Various factors contribute to this integrity and they are listed below, in the order of their contribution:

- ***Strength of the ligaments:*** The ligaments bind the bones together and being inelastic, provide firmness and strength;
- ***Tension in the surrounding muscles:*** When the movements of a joint exceed a limit, the muscles which

are antagonistic to the particular movement become tensed and restrict the movement; the joint surfaces are kept close to each other by such restriction. Even resting muscles around a joint exert a certain amount of tonic force on the joint, contributing to joint approximation (joint closeness);

- ***Force of cohesion:*** When the smooth articulating surfaces are in contact with each other, except for a thin layer of synovial fluid intervening, cohesion force between the two surfaces is created and tends to keep the surfaces approximated to each other;
- ***Interlocking of bony surfaces:*** This factor is not seen in all joints; in some joints, the opposing bony surfaces have reciprocal physical characters (like the ball [femoral head] fitting into a socket [acetabulum of hip bone] in the hip joint).

Factors Limiting Movements

Though joints, especially the synovial joints, are primarily designed for movements, the same, beyond a level or limit, will endanger the joint and its integrity. Several factors contribute to limit the movements in a joint. They are:

- ***Apposition of soft parts:*** The soft parts of the moving region come in contact with each other and the movement cannot proceed further; example is the pressing of the front of forearm on the front of arm in flexion of elbow;
- ***Locking of bones:*** This is not always seen; but in some joints, two bones may lock with each other to prevent further movement;
- ***Tension of ligaments:*** Tension increases in the adjacent ligaments and the movement is prevented from proceeding further;
- ***Passive insufficiency of muscles*** (also called ***ligamentous action of muscles***): The concerned muscles do not check the movement initially; but after the ligaments have restricted the movement, the muscles reinforce this restriction. A good example is the hamstring restriction on hip flexion when the knee is fully extended. Knee extension causes tension in the hamstrings; it is essential that the hamstrings relax during hip flexion; but they are not able to relax because of the already increased tension; this restricts flexion of the hip. Though the hip flexors are sufficiently able, the movement is restricted due to an insufficiency of the antagonists. Hence, it is called 'passive insufficiency'. The antagonistic muscle, instead of relaxing (and stretching), acts like a ligament and hence the name 'ligamentous action of muscle'.

Classification of Synovial Joints (Fig. 5.4)

Synovial joints vary in shape, size, form of the articular surfaces and in the movements performed.

Development

In a well developing embryo, the future bones are in the form of cartilaginous rods; and mesenchyme fills the gap between the rods. As development progresses, the outer portion of the mesenchyme condenses to become the fibrous capsule of the joint; inner portion gets hollowed out to form the joint cavity. As hollowing proceeds, synovial membrane develops on the inner aspect of the capsule from the remaining mesenchyme. By about the 8th week of intrauterine life, the developing joint resembles the adult joint in many respects: fibrous capsule, adjacent ligaments and synovial membrane are well developed; synovial fluid is secreted into the joint cavity.

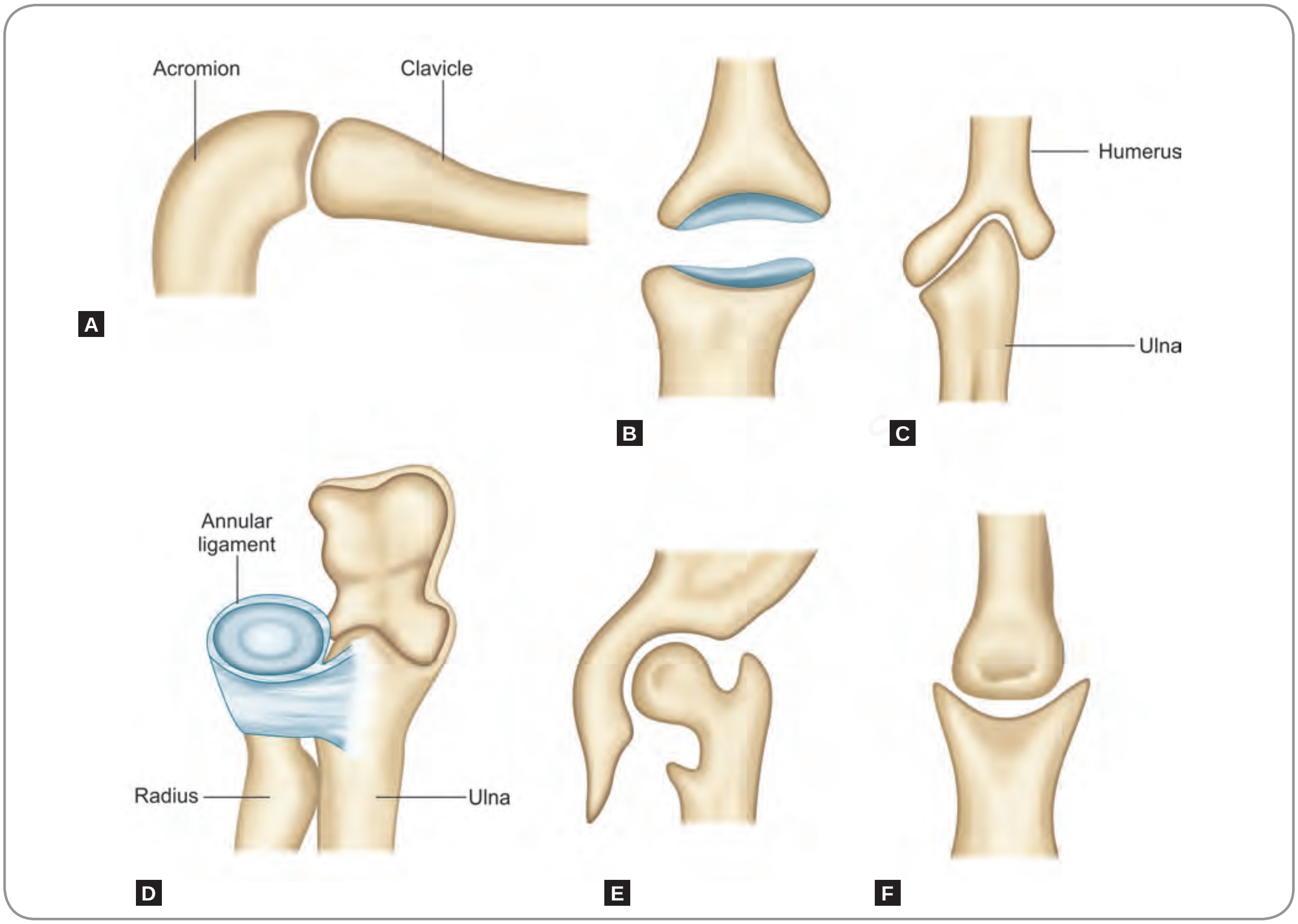
They are broadly classified as ***homomorphic*** and ***heteromorphic joints***; the articular surfaces in a homomorphic joint are similar in form and in a heteromorphic joint are dissimilar.

Movements occur around various axes. Keeping this in mind, the synovial joints may be classified as:

- ***uniaxial:*** Where movements occur around a single axis;
- ***biaxial:*** Where movements occur around two axes;
- ***polyaxial or multiaxial:*** Where movements occur around many axes.

Since the form of the articular surfaces is intricately related to the movements of the joint, the most commonly adopted classification is based on the form.

- ***Plane joint*** or ***gliding joint*** or ***arthroidal joint*** or ***articulatio plana:*** The opposing surfaces are relatively flat, almost equal in extent and the movement is a simple gliding movement; it is actually non-axial because gliding does not happen around any axis. ***Examples*** are the intercarpal and intertarsal joints (Fig. 5.4A).
- ***Saddle joint*** or ***articulatio*** or ***sellaris:*** The articular surfaces resemble a saddle. The surfaces are reciprocally concavoconvex. Each articular surface has both convex and concave areas and movements occur around two axes. The joint is thus biaxial and a typical ***example*** is the first carpometacarpal joint (Fig. 5.4B).
- ***Hinge joint*** or ***ginglymus:*** The articular surfaces are so arranged to permit movement around only one axis, like that of the hinge of a door. However, the axis here is not vertical (like the door) but transverse (like that of the lid of a box). The joint, therefore, is uniaxial; the cylindrical end of one bone fits into the trough of the opposing bone. Examples are the elbow and the ankle joints (Fig. 5.4C).
- ***Pivot joint*** or ***trochoid joint*** or ***articulatio trochoidea:*** Movement occurs around only one axis, which is the vertical axis. It resembles the hinge of a door. A more or less cylindrical articular surface rotates within a ring shaped articular surface or the ring rotates around the cylinder. This is also uniaxial;



Figs 5.4A to F: Different types of synovial joints (schematic representation) **A.** Plane joint **B.** Saddle joint **C.** Hinge joint **D.** Pivot joint **E.** Ball and socket joint **F.** Condyloid joint

examples are the joint between the atlas and the dens of axis (ring rotating around the cylinder) and the proximal radioulnar joint (head of radius rotates within a ring) (Fig. 5.4D).

- ***Ball and socket joint*** or ***articulatio spheroidea:*** One of the articular surfaces is spheroidal (like a sphere/ball) and articulates within the socket formed by the opposing articular surface. A wide range of movements are possible and occur around all the three perpendicular axes, making the joint multi-axial. Composite movements involving more than one axis also occur in such joints. Examples are the shoulder and the hip joints (Fig. 5.4E).
- ***Condyloid joint*** or ***articulatio condylaris:*** The articular surfaces are ball and socket; however, they are much smaller. Due to the disposition of muscles and ligaments, rotational movements around the vertical axis do not take place. This is a biaxial joint where movements occur around the anteroposterior (abduction-adduction) and the transverse (flexion-extension) axes. Examples are the metacarpophalangeal joints (Fig. 5.4F).
- ***Ellipsoid joint*** or ***articulatio ellipsoidea:*** This is a modification of the ball and socket joint. The articular surfaces, instead of being spheroidal, are ellipsoidal. Rotational movements are prevented due to the ellipsoidal surfaces. Example is the radiocarpal (wrist) joint.

Added Information

- Though the manubriosternal joint is often classified as a ***symphysis***, it is not a typical symphysis. To start with, it is a synchondrosis in the early part of intra-uterine life, but the hyaline cartilage is soon replaced by fibrocartilage. So, in a definitive form, the joint is a symphysis.
- While pulling on their fingers, some people are able to crack their knuckles. When one pulls on the joint, the suction force draws the respiratory gases out of the capillaries in the synovial membrane. All the gas bubbles coalesce and burst into the joint cavity. This produces the joint sounds and the ***crackling*** of the knuckles.

Clinical Correlation

- The articular cartilage derives nourishment from various sources. The peripheral zone of the cartilage is well nourished from the adjacent synovial blood vessels. This may sometimes lead to overgrowth of the cartilage and cause what is called 'lipping of the articular margin in osteoarthritis On the contrary, the central zone of the cartilage is less supplied and is prone to degenerative changes.
- A synovial joint receives blood vessels and nerve twigs from many sources. These branches and twigs come from varying directions and supply overlapping areas of the capsule. The arteries usually form a rich periarticular arterial network around the joint. Such multiple supply is of advantage to the joint. If some of them are injured, the rest can take charge and the joint function will not be compromised. Also, when movements compress a vessel or nerve, the others stay open and functional.
- Synovial joints are very well designed for use for several years. However, normal aging process starts in early adulthood and progresses gradually on the articular ends of bones, specially those of limbs. Degenerative changes occur in the articular cartilages and they lose their shock absorption and buffer functions. This results in the articular cartilages becoming more prone to wear and tear injuries and to injuries due to repeated friction. This condition is called degenerative joint disease or osteoarthritis; pain, stiffness, discomfort and restricted movements occur.
- The cavity of a synovial joint can be seen through an instrument that has a small telescope attached to it. It is called an arthroscope and the procedure is arthroscopy.
- Exercises help joints maintain their strength and viability. When a joint is exercised, synovial fluid is squeezed in and out of the articular cartilages. Thus, the cartilages are provided with nutrition. Also the related muscles are strengthened. However, over exercise of weight-bearing joints may cause an early onset of arthritis Exercising in swimming pools provides a good balance because buoyancy of water prevents over-stress on weight-bearing joints.
- ***Sprain:*** This is a condition where the ligament of a joint is overstretched or torn. Ligaments of knee, ankle and lower spine suffer the most. The condition is extremely painful and the joint cannot be moved because of intense pain. If the ligament is partially torn, it will heal on its own but slowly. Completely torn ligament requires surgical repair or replacement.
- ***Dislocation:*** This is a condition where the bones of a joint are forced out of their compactness and alignment. Pain and restricted joint movements are present. Injuries cause dislocation. Joints of shoulder, jaw and fingers (especially thumb) suffer the most. A joint that has suffered dislocation is likely to suffer the same fate again and again. When it dislocates the first time, the joint capsule and ligaments get overstretched and thus become loose. This looseness predisposes to subsequent dislocations.
- ***Arthritis:*** The term indicates all inflammatory and degenerative diseases of joints. As noted above, osteoarthritis is a degenerative condition related to aging process. Rheumatoid arthritis is another type which is inflammatory in nature. More common in women, it is a complicated disease with associated osteoporosis, muscle weakness and heart problems. Small joints of hands and feet are more affected. Gouty arthritis is a condition where, in certain people, there are abnormally high levels of uric acid in blood and tissue fluids. Uric acid gets deposited as urate crystals in synovial membranes, causing an inflammatory reaction. Gout is more common in men and affects larger joints.

Multiple Choice Questions

1. A synarthrosis is:
   a. A simple joint
   b. An immobile joint
   c. A partially mobile joint
   d. A freely mobile joint

2 The sagittal suture of the skull is an example of:
   a. Plane suture
   b. Serrate suture
   c. Dentate suture
   d. Squamous suture

3. When the intervening fibrous tissue between two bones forms an interosseous membrane, the joint is:
   a. Suture
   b. Gomphoses
   c. Syndesmosis
   d. Synostosis

4. One of the following s not a symphysis. Which one:
   a. Manubriosternal joint
   b. Joint between pubic bones
   c. Diaphyseoepiphyseal joint
   d. Joints between bodies of adjacent vertebrae

5. Nutrition to articular cartilage is provided by:
   a. Synovial fluid
   b. Vasculature in synovial membrane
   c. Vasculature in underlying bone
   d. All of the above

ANSWERS

1. b **2.** b **3.** c **4.** c **5.** d

Clinical Problem-solving

Case Study 1: A 52-year-old woman developed complaints of joint stiffness, pain and restricted movements. Whenever she moved her right knee, she had severe pain associated with stiffness.

- What is the probable ailment she was suffering from?
- What was the cause for the ailment?
- People of which age group suffer from such an ailment?

Case Study 2: A 26-year-old man was jogging down the road. He tripped and fell. His right ankle got twisted. The man soon developed a big swelling and intense pain. The doctor who treated him told that though no surgery was required, it will take some weeks before he can be completely alright.

- What probably had happened to the man's ankle?
- Which part of a joint gets affected in this condition?
- Why should it take long for the man to become completely alright?

(For solutions see Appendix).

Chapter 6

Nerves and the Nervous System

Frequently Asked Questions

- What are the various types of neurons?
- Describe a typical multipolar neuron and its parts.
- Discuss the functioning of a synapse.
- What is neuroglia?
- Describe myelination. Add a note on its importance.
- Describe a typical reflex arc.

Nerves are the wires of the body's act on circuit and are responsible for our thoughts, emotions, actions and intelligence. Nerves and nerve cells, along with supporting cells make up the nervous system which is the master communicating and controlling system of the body.

It is easier to understand the basics of nervous system if the overall functioning and classification are studied first before moving over to the study of individual components like cells.

The human body has a single, highly integrated and complete nervous system. All its component parts are related to each other both by structure and function. However, for the sake of convenience, it is customary to classify the nervous system into the ***central nervous system*** and the ***peripheral nervous system*** (Figs 6.1 and 6.2). The autonomic nervous system, which has its distribution through both of them is sometimes classified as a separate component.

CENTRAL NERVOUS SYSTEM (FIG. 6 2)

The ***central nervous system*** (CNS) consists of the brain and the spinal cord which occupy the cranial cavity and

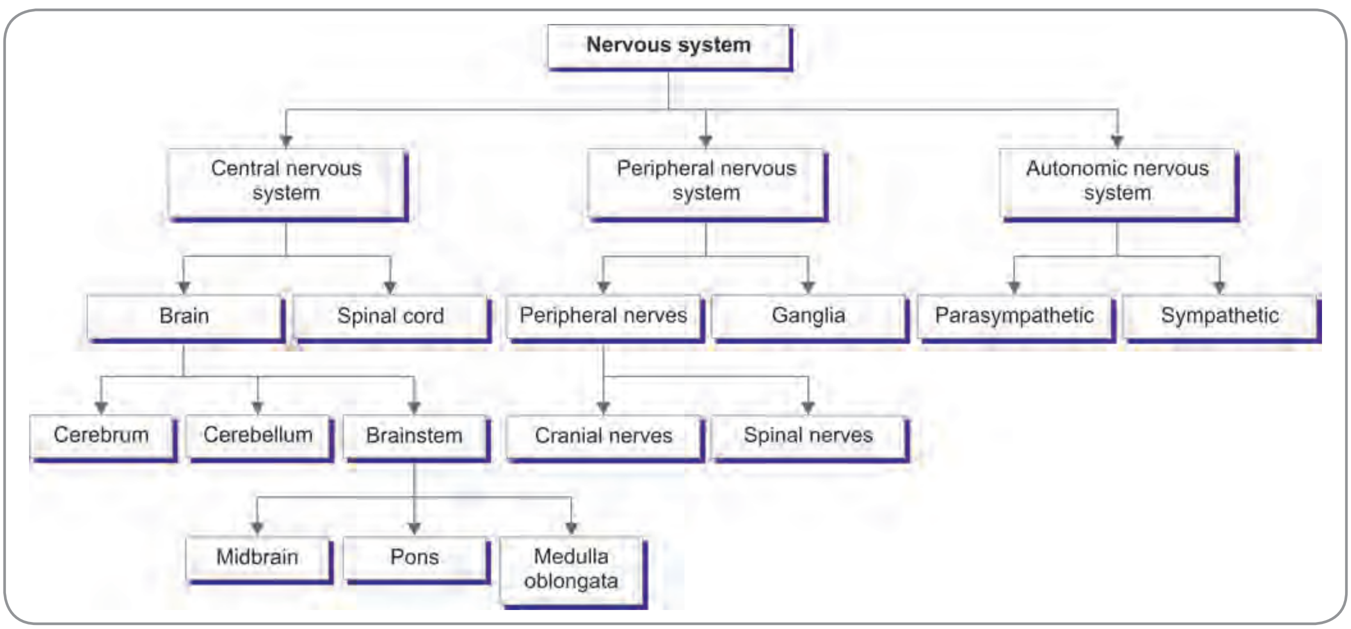


Fig. 6.1: Divisions of nervous system

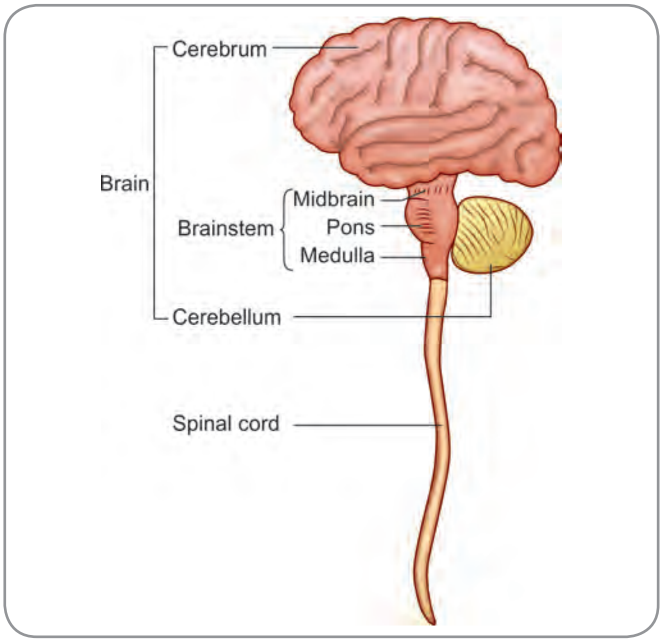


Fig. 6.2: Diagram showing parts of the central nervous system

the vertebral canal respectively. The CNS (as it is referred to) is the overall command centre of the body.

- It receives sensory information and processes them;
- It gives out motor commands based on memory, past experiences, present situations and cu rent necessity.

PERIPHERAL NERVOUS SYSTEM

That part of nervous system outside the central nervous system is called the ***peripheral nervous system*** (PNS). It consists of the nerves which extend from brain and spinal cord to different parts of the body (and vice versa) All the nerves together can be likened to a huge network that functions as the electrical circuit of the body. Nerves extending from and to the brain are called ***cranial nerves***. Nerves extending from and to the spinal cord are called the ***spinal nerves***. Nerves are the communication channels which connect different parts of the body with the nervous system.

The peripheral nervous system is further sub-divided into very many ways, based on functions and effects produced.

One way of sub-classification is to consider the receptive and effective capabilities. Thus, we have the ***sensory*** and the ***motor*** divisions. The ***sensory*** or ***afferent*** (Latin.affero=to bring to) division consists of nerves which carry signals from the sensory receptors to the CNS. The ***motor*** or ***efferent*** (Latin.effero=to bring out) division consists of nerves which carry signals from the CNS to different parts of the body. Depending on the command received, the end organ either contracts (if it is a muscle) or secretes (if it is a gland).

The peripheral nervous system can also be sub-classified based on the region of the body served. A basic pattern of dividing the body regions will be in relation to the ventral body cavity. All structures external to the ventral body cavity (like the skin, skeletal muscles and bones) form the ***somatic body region***; all structures within the ventral body cavity (like the digestive organs, heart, lungs, kidneys and so on) constitute the ***visceral body region***. Adding the sensory and the motor subdivisions to these, we have the following:

- ***Somatic afferent:*** Sensory innervations of the outer parts of the body;
- ***Somatic efferent:*** Motor innervation of the outer parts of the body;
- ***Visceral afferent:*** Sensory innervation of the inner parts of the body;
- ***Visceral efferent:*** Motor innervation of the inner parts of the body.

These can now be seen in further detail.

- ***Somatic afferent:*** This can be divided into the general somatic afferent system and the special somatic afferent system. The ***general somatic afferent system*** includes senses whose receptors are widespread (general=widespread) and found almost throughout the body. These senses include touch, pressure, pain, temperature, vibration, joint sense and sense of position of a body part (proprioception). The ***special somatic afferent system*** involves somatic senses whose receptors are confined to special locations in the body, i.e., they are not widespread (special=localizsd in specific areas). Most of the special senses are confined to the head of the body and include vision, hearing, smell and equilibrium.
- ***Somatic efferent:*** This relates to the motor supply to all skeletal muscles of the body (except the pharyngeal arch musculature). Since we have voluntary control over the skeletal muscles, the somatic efferent system is also called the voluntary nervous system; and since skeletal muscles are distributed all through the body, it is a ***general somatic efferent system*** (there is no special somatic efferent system).
- ***Visceral afferent:*** This is divided into the ***general visceral afferent*** and the ***special visceral afferent***. Pain, temperature and stretch sense received from various systems of the body like the digestive tract, urinary tract, genital tract and other organs form the ***general visceral afferent system***. Nausea and hunger are also included in this group. The ***special visceral afferent system*** involves taste, which is special because the receptors are localised to a small area.
- ***Visceral efferent:*** This is divided into the ***general visceral efferent system*** and the ***special visceral efferent system***. Motor innervation to smooth muscles

of viscera, to cardiac muscles, and to glands form the ***general visceral efferent system***. Since the visceral smooth muscles or the cardiac muscles are not in our voluntary control, it is called the ***involuntary nervous system***. The general visceral efferent system is better known by its popular name, the ***autonomic nervous system***. The ***special visceral efferent system*** involves innervations to the pharyngeal arch musculature. Though this is skeletal musculature, it originates and develops around a viscus, namely pharynx The pharyngeal musculature is also localised to the head and neck regions, justifying its classification as special.

CELLS OF NERVOUS TISSUE

There are two types of cells in the nervous tissue, namely (1) the ***neurons*** and (2) the ***supporting cells***. The nervous system is highly cellular, meaning the cells are closely packed and there is very little extracellular space. The cells are also well connected within themselves.

NEURONS

Neurons (or ***neurocytes***) (Fig. 6.3) are the basic structural units of the nervous system. These are specialised cells capable of conducting electrical impulses from one part of the body to the other. Crores of neurons exist in the human body. The neurons have special characteristics. These are as follows:

- ***Impulse transmission:*** The electrical signals which are transmitted by the neurons are called ***nerve impulses*** or ***action potentials***. The signals are transmitted along the plasma membrane of the neurons. Basically, an impulse is the reversal of electrical charge that travels along the membrane.
- ***Longevity:*** Neurons do not decline in their ability for a long time or under normal circumstances. They can live and function for a life-time (averaging 100 years).
- ***Undividing:*** As the developing neurons take up their roles as a part of the nervous system, they lose their ability to divide. So, if destroyed they cannot be replaced.
- ***High metabolic rate:*** In line with their continuous and high capability to work, their demand for oxygen and glucose is also high. So, their metabolic rate is high.

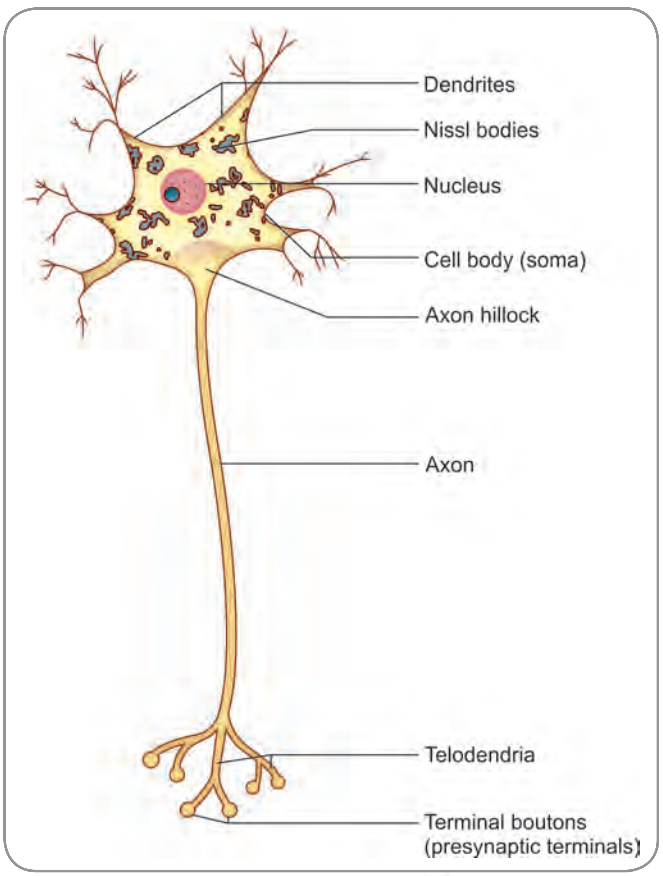


Fig. 6.3: Diagram showing the main parts of a typical neuron

Parts of a Neuron

A neuron has a ***cell body*** called the soma and one or more ***cellular processes***.

- ***Cell body:*** Also called ***soma*** (Greek.soma=body) or ***perikaryon*** (Greek.peri=around, karyon=kernel; nucleus of a cell is likened to a kernel and perikaryon means 'around the nucleus'). The cell has a large ***nucleus***, located almost at the centre of the cell. The nucleus contains a ***nucleolus***. The nucleus is surrounded by the cytoplasm. Apart from regular ***cellular organelles***, the cytoplasm also contains the ***Nissl bodies*** (named after Franz Nissl, a Heidelberg neurologist) or granules. These chromophilic (colour-loving; easily stainable) bodies are clusters of rough endoplasmic reticulum and ribosomes. These clusters renew the plasma membranes of the neuron. Bundles of neurofilaments run in a network in the cytoplasm; they keep the cell intact and prevent it from being torn when it is subjected to tensile forces. ***Lipofuscin granules*** also occur in the cytoplasm; these are the byproducts of lysosomal activity and are yellow-brown in colour.
- ***Cellular processes:*** The characteristic feature of a neuron is the presence of extensions from the cell body. These extensions are called processes. There are two types of processes, namely the (1) ***axons*** and (2) ***dendrons***.
  - ***Axon:*** Each neuron has a single axon (Greek. axone=axis). It arises from a conical part of the cell body called the ***axon hillock*** and then tapers to a thin process. The axon remains remarkably uniform in diametre throughout its length. The axon has all the organelles that a cell has, except the Nissl granules and Golgi bodies. Neurofilaments, Actin filaments

and microtubules provide structural strength to the axon and help in transport of substances from and to the cell body. Such movement of substances is called ***axonal transport***. Axons are the ***distributors*** and so conduct impulses away from the cell body. The length of axons varies from cell to cell. Motor neurons which control the muscles of the foot are present in the lumbar spinal cord and the axons extend from here to the muscle in the foot, thus extending for a distance of more than 3 to 4 feet. An axon is also called a ***nerve fibre***.

- ***Dendron:*** This is also called ***dendrite*** (Greek. dendron=tree, dendritez=relating to a tree). A neuron has several dendrons, making them look like the branches of a tree. All cell organelles are present in the dendrons; Nissl granules extend into the basal parts of dendrons. The presence of dendrons increases the surface area of the neuron, thereby increasing the area available to receive signals and impulses from other neurons. The dendrons, therefore, are ***receptive areas***, conducting signals towards the cell body. The type of signals conducted by dendrons are ***graded potentials*** (and not action potentials like the axons).

Generally, axons do not branch like the dendrons. Some axons do give out branches; these are called ***axon collaterals***. However, an axon, at its end point, divides into several branches; these are called the ***telodendria***. Each ***telodendrion*** (Greek.telos=end) ends in a button-like structure called the ***axon terminal*** or ***end bulb*** (or end bouton or simply, bouton). The end bulb comes into contact with another neuron through a synapse.

Types of a Neuron (Figs 6.4 and 6.5)

Neurons are classified in varied ways. The most common way of classifying is to consider the processes and classify according to the number of processes. The other method is to classify based on the functions of the neuron.

- ***Based on processes:*** Neurons are classified into multipolar, bipolar and unipolar (Fig. 6.4).
  - ***Multipolar neuron:*** It is a neuron with many processes, of which only one is an axon and the rest are dendrons. Many of the neurons of the body belong to this type. All the motor neurons which control the skeletal muscles and those comprising the autonomic nervous system are multipolar neurons.
  - ***Bipolar neuron:*** It is a neuron with two processes. One of them is the axon and other the dendron. Such neurons are usually found in organs of special senses like the inner ear, the nose and the retina and are sensory. However, this type is rare

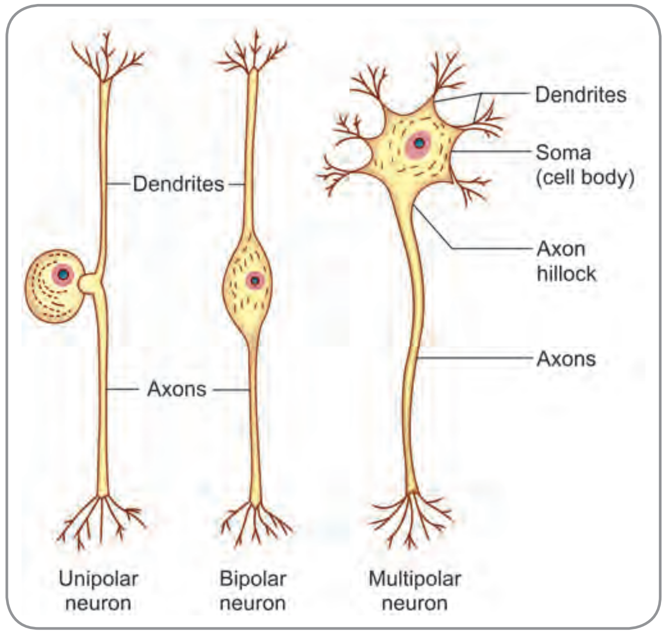


Fig. 6.4: Unipolar, bipolar and multipolar neurons

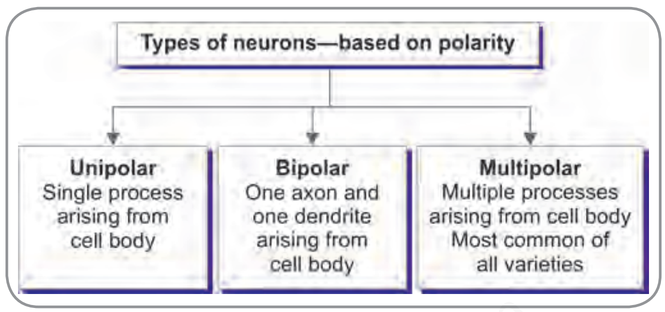


Fig. 6.5: Types of neurons—anatomical classification

  - ***Unipolar neuron:*** It is a neuron with only one process. Though at the first look only a single process is seen, a closer examination would reveal the single process to divide a short distance from the body into two processes. One of the processes carries information to the cell body (functioning as an axon) and is the ***central process***. The other process receives information from periphery or receptors in the peripheral parts of the body (receiver acting like a dendron) and so is called the ***peripheral process***. The neuron had started with two processes but during development, the processes had come closer to each other and had fused. Therefore, the neuron is more precisely called the ***pseudounipolar neuron***. This type makes up the typical sensory neurons.
- ***Based on functions:*** Neurons can be classified into motor, sensory and interneurons.
  - ***Motor neurons:*** Also known as ***efferent neurons***. They carry impulses from the central nervous system (CNS) to the effector structures. Most of the motor

neurons are multipolar; their cell bodies are located in the CNS.

- ***Sensory neurons:*** Otherwise called ***afferent neurons***. They carry impulses from the sensory receptors to the CNS. Almost all the sensory neurons are unipolar and are located in ganglia (singular, ganglion) outside the CNS.
- ***Interneurons or association or internuncial neurons:*** (Latin.inter = between, nuncius = messenger). They are located only in the CNS and lie between the motor and sensory neurons. They integrate information and serve as conduits of information processing. More than 98% of the neurons in the body are interneurons. They are multipolar but vary in size and in pattern of branching.

Synapses (Fig. 6.6)

From the foregoing discussion, it can well be understood that neurons communicate with each other. The physical basis of communication is a ***synapse***. A synapse can be defined as a ***neuronal junction*** through which information is transferred from one neuron to the other. However, the passage of information is unidirectional; it travels in one direction only.

Information arrives at a synapse in the form of signals. The neuron that conducts signals to a synapse is a ***pre-synaptic neuron***. The neuron that receives and sends the information away from the synapse is the ***postsynaptic neuron***. A neuron can act as both presynaptic and post-synaptic, receiving information from some neurons and sending information to some others.

Various parts of the communicating neurons come into contact with each other. Depending on the parts which form the synapse, different types are described as follows:

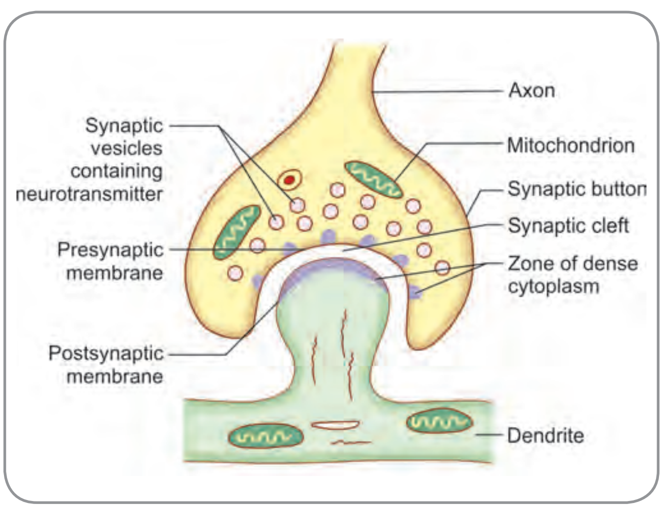


Fig. 6.6: Structure of a typical chemical synapse as seen under electron microscope

- ***Axodendritic synapse:*** Synapse is between the axon of the presynaptic neuron and the dendrites of the postsynaptic neuron.
- ***Axosomatic synapse:*** Synapse is between the axon of the presynaptic neuron and the soma of the postsynaptic neuron.
- ***Axoaxonic, dendrodendritic and dendrosomatic*** synapses are also seen, but are extremely rare and are less understood.

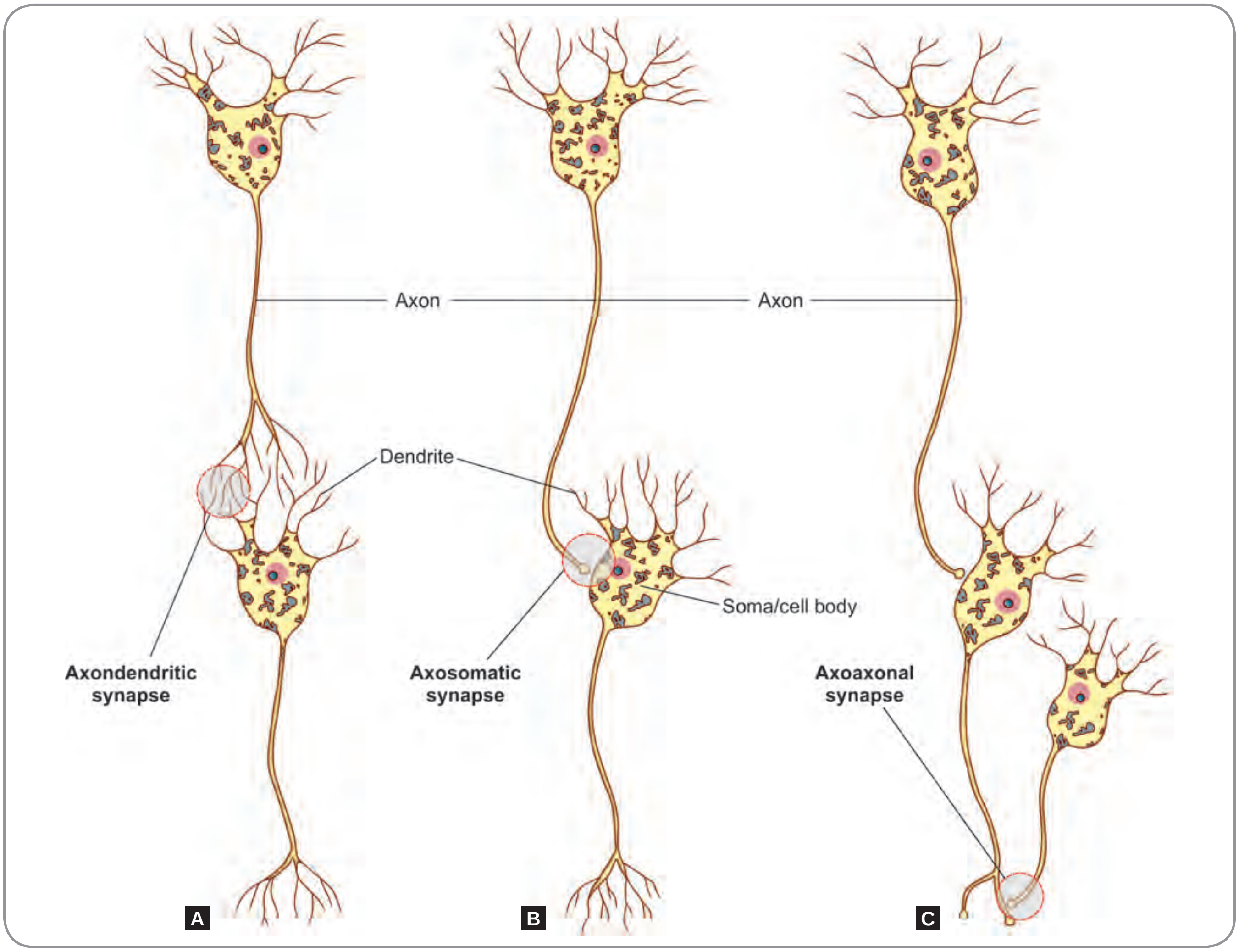
Structure and Functioning of a Synapse (Fig. 6.7)

It is easy to study the commonest of the synapses, namely, the ***axodendritic synapse***. The axon of the presynaptic neuron relays to the dendron of the postsynaptic neuron. At the site of the synapse, the plasma membranes (called the ***presynaptic*** and ***postsynaptic membranes***) of the two participating neurons are separated by a narrow gap called the ***synaptic cleft***. The presynaptic axon is enlarged into a bulb called the ***axon terminal***. The axon terminal contains several ***synaptic vesicles***. These are membrane bags filled with neurotransmitters. Since secretion of neurotransmitters requires a lot of energy, mitochondria are also abundantly seen in the axon terminal. On the postsynaptic side, the postsynaptic membrane shows many receptors. These receptors are specific to the neurotransmitters

Let us say, an impulse is travelling down the presynaptic axon. This impulse needs to be transmitted to the postsynaptic dendron. The process of impulse transmission from one neuron (or its parts) to another neuron is called ***relay***. How does relay happen in a synapse? The impulse travelling in the axon provides the signals for release of neurotransmitters. The synaptic vesicles which contain the neurotransmitter fuse with the presynaptic membrane and release the transmitter into the synaptic cleft through the process of ***exocytosis***. The released neurotransmitter crosses the synaptic cleft and reaches the postsynaptic membrane. It binds to the receptors. This binding affects the membrane charge on the postsynaptic neuron and an impulse is generated in that neuron for further transmission.

SUPPORTING CELLS

The supporting cells of the nervous system are non-nervous (non-excitable), but are closely associated with the neurons and nerve fibres. There are different types of supporting cells and each one has a different function. However, the basic function of all these types of cells is to provide a supportive base for the neurons and fibres. All parts of a neuron except the area that participates in a synapse are covered by supporting cells. It is necessary that such a covering is provided; the covering insulates the neuronal tissue and helps in faster transmission; also,



Figs 6.7A to C: Various types of chemical synapses **A.** Axodendritic synapse **B.** Axosomatic synapse **C.** Axoaxonal synapse

impulses of one neuron are prevented from interfering with the electrical activity of adjacent neurons (much like the insulation that we provide for electrical wires). Supporting cells are generally called the ***neuroglial cells*** or ***glial cells*** or collectively the ***neuroglia*** (Greek. neur=nerve, glia=glue). Some authors restrict the term to the supporting cells of CNS only.

Supporting Cells in the Central Nervous System

Glial cells also have a central body and branching processes. However, they are different from the neurons in that they are much smaller in size and can divide throughout life. There are four types of neuroglial cells, namely (1) ***astrocytes***, (2) ***oligodendrocytes,*** (3) ***microglial cells*** and (4) ***ependymal cells***.

- ***Astrocytes (Fig. 6.8):*** These are star-shaped cells (Greek. astron=star) and are the most abundant of the glial cells. True to their name, astrocytes have a central soma from which several processes radiate. The processes end in

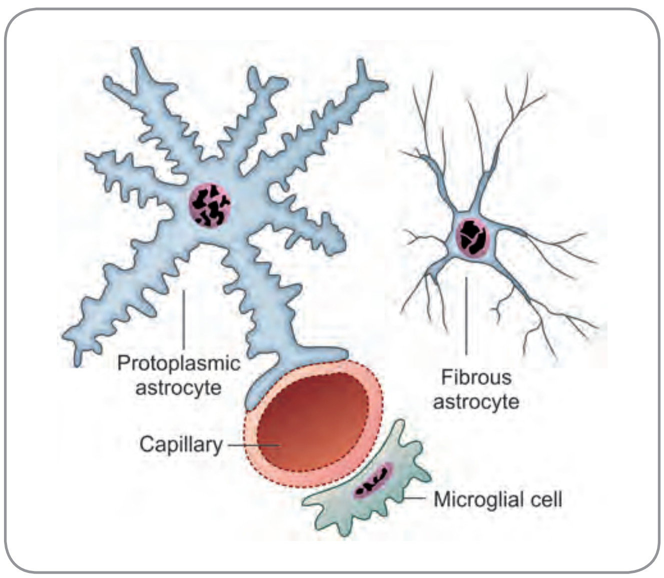


Fig. 6.8: Astrocytes and macroglial cells—Note the peri-vascular feet of astrocytes forming a sleeve around a capillary

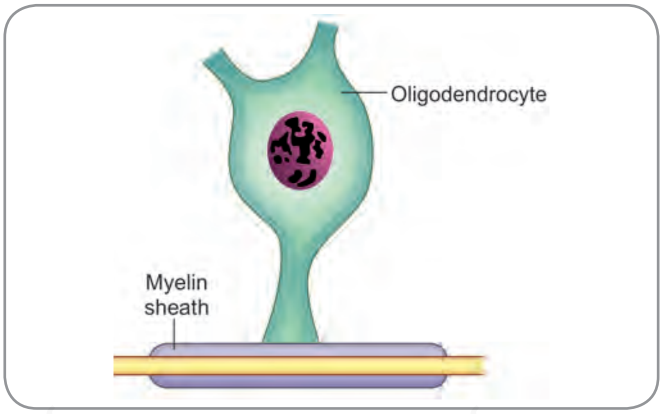


Fig. 6.9: Oligodendrocyte and its relationship to a neuron

bulbs, some of which cling to neurons and others to capillaries. Astrocytes play a major role in maintaining the ionic environment around the neuron and also help to recapture the neurotransmitters released from neurons and 'thus' recycle them.

- ***Oligodendrocytes (Fig. 6.9):*** These are cells with less number of processes than other supporting cells and hence, the name (Greek.oligos=few). They collect along bigger axons; wrap their cell processes around these axons and form myelin sheaths.
- ***Ependymal cells:*** (Greek.ep=upper, endyma=garment; upper garment). These cells form a lining layer of the central cavity of the brain and the spinal cord. They have cilia to help movement of cerebrospinal fluid. They also form a layer of permeability between the cerebrospinal fluid and tissue fluid of CNS
- ***Microglial cells:*** These are the smallest (Greek. micron=small) and the least abundant of the glial cells. Their cell bodies are ellipsoidal and their processes have pointed ends. The microglial cells are functionally the macrophages or phagocytic cells of the CNS. They engulf invading microorganisms and dead or diseased neuronal cells and remove them (Fig. 6.8)

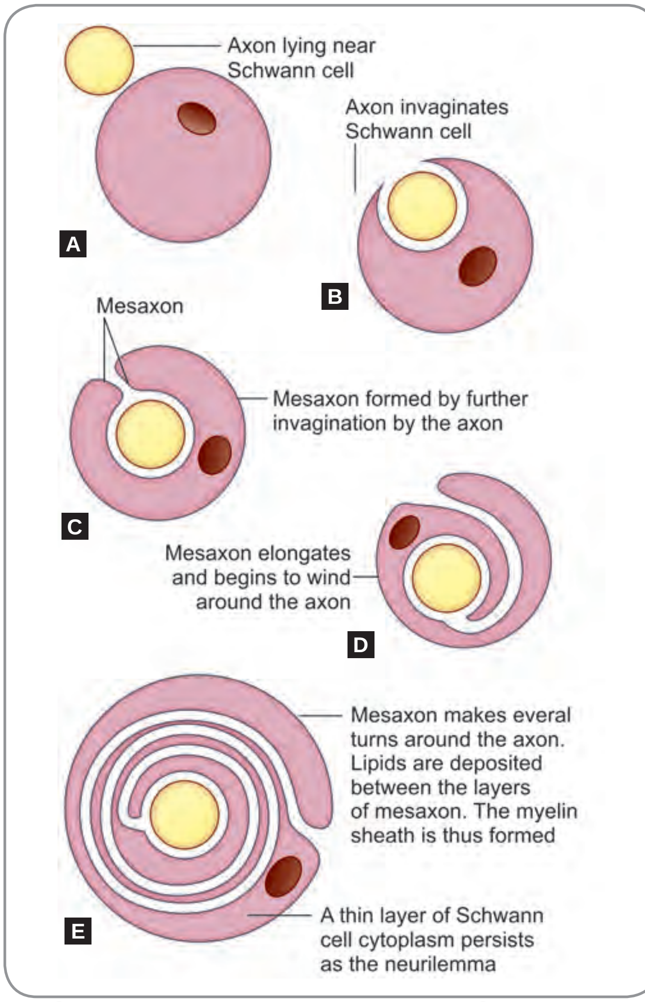
Supporting Cells in the Peripheral Nervous System

There are two types of supporting cells in the PNS, namely (1) ***satellite cells*** and (2) ***Schwann cells***. These cells do not have branching processes as the glial cells, but they form a supportive scaffolding for the neurons in the PNS.

- ***Satellite cells:*** These are small cells which surround the cell bodies of neurons in ganglia. They appear like moons around a planet and hence the name.
- ***Schwann cells:*** These cells are also called the ***neurilemmocytes***. They surround the axons in the PNS and form myelin sheaths around them.

Myelin and Myelination (Fig. 6.10)

The thicker axons of the body are surrounded by a fatty substance called the ***myelin***, in the form of a segmented



Figs 6.10A to E: Stages in the formation of the myelin sheath by a Schwann cell—The axon, which first lies near the Schwann cell. **A.** invaginates into its cytoplasm **B and C.** and comes to be suspended by a mesaxon. The mesaxon elongates and comes to be spirally wound around the axon **D and E.** Lipids are deposited between the layers of the mesaxon

myelin sheath. The myelin sheath is actually the plasma membrane of the supporting cell. The plasma membrane is arranged in a roll fashion around the axon and provides insulation. This insulation prevents leakage of electrical current (the electric current produced as a result of the impulse) from the axon; interference of the electrical activity of a neuron with the electrical activities of adjacent neurons is, therefore, prevented and speed of conduction of the electrical impulse along the axon is increased.

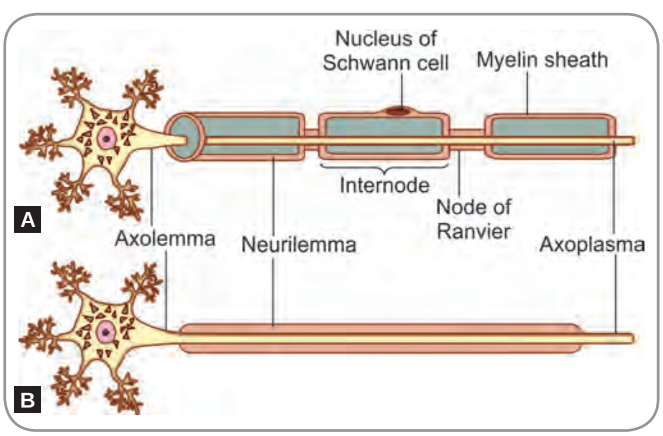
Myelination process in the PNS (Fig. 6.10) can be studied in detail to understand the formation of the myelin sheath. To start with, the axon to be myelinated and the Schwann cell remain adjacent to each other. The Schwann cell gets indented to receive the axon. Slowly and gradually, the Schwann cell wraps around the axon As myelination proceeds, the wrapping continues around and around repeatedly, leading to a jelly-roll of myelin around the axon. In the initial stages, the wrapping is

loose but becomes tighter subsequently. As a result, the cytoplasm and the nucleus of the Schwann cell are pushed to the area which is superficial. When the cross-section of a myelinated nerve fibre is studied, the Schwann cell plasma membrane is seen in several concentric layers around the axon. This coil of concentric layers is the ***myelin sheath***. Superficial to the myelin layers are the cytoplasm and the nucleus of the Schwann cell. This superficial material forms the ***neurilemma*** (Greek.lemma=husk or covering). An axon is very long and so has several Schwann cells forming myelin layers along it. Adjacent Schwann cells along the axon do not touch each other and so, the myelin sheath has gaps in those places. These gaps are called the ***nodes of Ranvier*** (named after Louis Ranvier, a French pathologist) or ***neurofibral nodes***. The nodes occur at regular intervals of about 1 mm. The nodes help in rapid transmission of impulses; as the impulses travel along the axon, instead of slowly going through the myelinated part of the fibre, they jump from one node to another and make a faster travel.

Axons which are surrounded by myelin are called ***myelinated***; thinner and smaller axons are not surrounded by a myelin sheath and so are ***unmyelinated*** (Fig. 6.11). The unmyelinated axons also have adjacent Schwann cells, but the latter do not wrap around the former. Several axons lie close to a Schwann cell; these axons merely indent into the Schwann cell. Ten to fifteen unmyelinated axons indent into a single Schwann cell. As the axon indents into the Schwann cell, that part of the Schwann cell forms the neurilemma of the axon.

Myelinated axons are thicker and rapidly conducting; unmyelinated axons are thinner and slowly conducting (Table 6.1).

Axons in the CNS also get myelinated. Oligodendrocytes form the myelin sheaths. But there is a difference between, the way a Schwann cell forms a myelin sheath and the way an oligodendrocyte forms one. Each oligodendrocyte



Figs 6.11A and B: A. Myelinated nerve fibre
B. Unmyelinated nerve fibre

Table 6.1: Differences between myelinated and Unmyel nated nerve fibres

Unmyelinated	Myelinated
Devoid of myelin sheath	Covered by myelin sheath
Surrounded by Schwann cells	Schwann cells form myelin sheath which surrounds the nerve fibres
Slow speed of transmission	Fast speed of transmission of nerve impulse

has several processes; each of these processes wraps around an axon. Nodes of Ranvier are also present, but are more widely spaced. As in the PNS, thinner axons are unmyelinated, but are merely covered by processes of other glial cells

Thus, in the CNS, each oligodendrocyte contributes myelin to several axons and in the PNS, each Schwann cell contributes myelin to only one axon; in the PNS, an axon receives its myelin sheath from many Schwann cells.

Composition of Myelin Sheath

Myelin contains protein, lipids, and water. The main lipids present include cholesterol phospholipids, and glycosphingolipids. Other lipids are present in smaller amounts.

Functions of the Myelin Sheath

- The presence of a myelin sheath increases the velocity of conduction (for a nerve fibre of the same diameter).
- It reduces the energy expended in the process of conduction.
- It is responsible for the colour of the white matter of the brain and spinal cord.

NERVE (FIG. 6.12)

What is nerve?
To the naked eye, the ne ve appears and be a cord like structure. It is present in the PNS A nerve consists of many nerve fibres arranged in parallel bundles and surrounded by various laye s of connective tissue.

The bundles of nerve fibres found in CNS are called ***nerve tracts*** while the bundles of nerve fibres found in PNS are called ***nerves***.

Basic Structure of a Nerve Fibre

Each nerve fibre has a central core formed by the axon. This core is called the ***axis cylinder***. The plasma membrane surrounding the axis cylinder is the ***axolemma***.

The axis cylinder is surrounded by a myelin sheath. This sheath is in the form of short segments that are separated at short intervals called the ***nodes of Ranvier***. The part

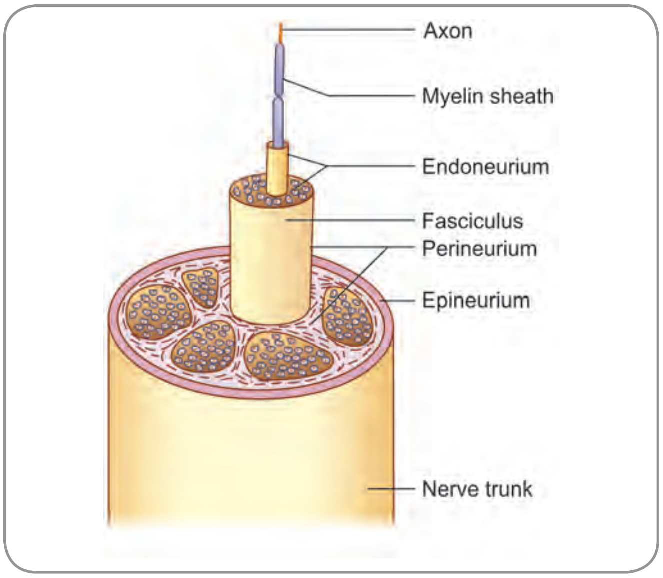


Fig. 6.12: Diagram showing the connective tissue supporting nerve fibres of a peripheral nerve

of the nerve fibre between two consecutive nodes is the ***internode***.

Each segment of the myelin sheath is formed by one Schwann cell.

Outside the myelin sheath, there is a thin layer of Schwann cell cytoplasm and an external lamina (similar to the basal lamina of epithelium). This layer of cytoplasm and external lamina is called the ***neurilemma***. Neurilemma is important in the regeneration of peripheral nerves after their injury.

Note: Such neurilemma is absent in oligodendrocytes that form myelin sheath in CNS. Hence, regeneration in the CNS is not possible.

Each nerve fibre is surrounded by ***endoneurium***. This is a layer of connective tissue. The endoneurium holds adjoining nerve fibres together and facilitates their aggregation to form bundles or ***fasciculi***.

Each fasciculus is surrounded by the ***perineurium*** that is a thicker layer of connective tissue The perineurium is made up of layers of flattened cells separated by layers of collagen fibres. The perineurium probably controls diffusion of substances in and out of axons.

A very thin nerve may consist of a single fasciculus, but usually a nerve is made up of several fasciculi. The fasciculi are held together by the **epineurium**. This is a fairly dense layer of connective tissue that surrounds the entire nerve.

Though the following terms sound similar, their meanings should well be appreciated. A neuron is a nerve cell. A nerve fibre (or simply, fibre when referring to the nervous system) is an axon. A nerve is a collection of nerve fibres, in case of a small nerve; a collection of nerve fasciculi, in case of a large nerve. The nerve also include as the connective tissue coverings of the fibre (endoneurium), fasciculus (perineurium) and the nerve itself (epineurium) and the blood vessels which nourish the nerve fibres and their coverings (vasa nervorum).

Dissection

The true nature of a nerve can be felt when it is rolled between one's fingers. There is no lumen as in arteries or veins. It feels full and thick and, thus, cannot be compressed. Because of the fullness (since no lumen), it is possible to roll a nerve between the thumb and the forefinger; a vessel cannot be rolled (on rolling, a vessel will tend to fold).

Types of Nerves

Nerves belong to the PNS and are classified into two major groups, namely, the ***cranial nerves*** and the ***spinal nerves***.

- ***Cranial nerves:*** These are nerves which emerge from the brain. They are usually indicated by a descriptive name (examples: facial nerve is the nerve related to supply of face; trochlear nerve is the nerve that runs through a pulley or trochlea) or by Roman numerals (cranial nerve V, XII and so on). There are ***twelve pairs of cranial nerves***; of these twelve, only ***eleven*** really arise from the brain; the left out pair of eleventh cranial nerves arise from the spinal cord.
- ***Spinal nerves:*** These are nerves which emerge from the spinal cord. Since they arise in pairs (one for each side) from a particular segment of the spinal cord, they are also called the ***segmental nerves***. There are ***31 pairs of spinal nerves*** for 31 spinal segments. The spinal nerves are indicated by a letter and a number; the letter corresponds to the spinal segment (C=cervical, T=thoracic, L=lumbar, S=sacral and C=coccygeal) and the number to the superior-to-inferior order of the particular segment (T3=thoracic third segment; L4=lumbar fourth segment).

Typical Spinal Nerve (Fig. 6.13)

Spinal nerves are seen to emerge from the spinal cord in the form of rootlets. The anterior rootlets join together to form the ***anterior nerve root*** (or ***ventral nerve root***); the posterior rootlets join to form the ***posterior nerve root*** (or ***dorsal nerve root***).

- ***Anterior nerve root:*** These consist of efferent fibres which arise from motor neurons present in the ventral horns of the spinal cord. The fibres go to the effector organs located peripherally.
- ***Posterior nerve root:*** The consist of afferent fibres. On the posterior root is a posterior root ganglion (or

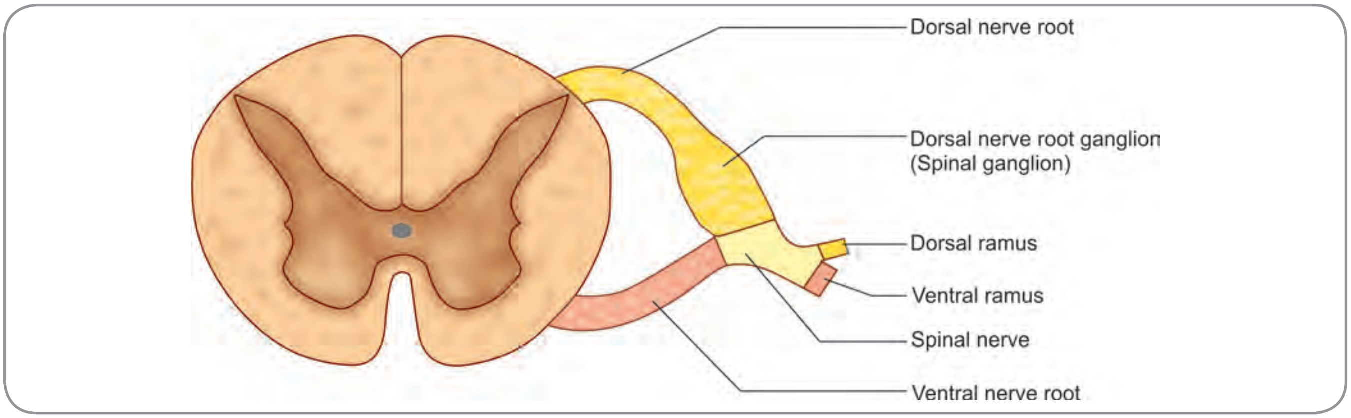


Fig. 6.13: Typical spinal nerve

the sensory ganglion or the dorsal root ganglion) that has a collection of sensory neurons. These neurons are pseudounipolar; their peripheral processes run to the sensory receptors in the periphery and their central processes run to the spinal cord.

The two roots unite and form a mixed nerve (having both motor and sensory components). This is known as the ***spinal nerve***. The spinal nerve divides into ***two rami*** (singular, ramus; Latin.ramus=branch), namely (1) ***ventral*** (or ***anterior primary***) ***ramus*** and (2) ***dorsal*** (***posterior primary***) ***ramus***. Both rami contain motor and sensory fibres (*Note* that the roots of a spinal nerve are either motor or sensory but the rami are both).

- ***Posterior primary rami:*** Supply the joints of the vertebral column, the deep muscles of the back and the skin over the particular segment. As a rule, these rami do not form networks with similar rami above and below and remain separate.
- ***Anterior primary rami:*** They will have to supply the rest of the areas of the body. These areas are the anterior and lateral regions of the trunk and the upper and lower limbs. Those anterior primary rami which supply the trunk retain their segmental pattern and distribution. But the same is not possible in relation to the limbs. The limbs, during development, have grown out as extensions from the body segments. However, to have effective functioning, the various components of the limb get grouped in different ways. The roots (the places where the concerned limbs get attached to the trunk) of limbs are compact. So, the anterior primary rami which supply the limbs unite to form plexuses (Latin. Plexus=braid). These are the ***somatic nerve plexuses***; the component fibres intermingle n a plexus and from it emerge a new set of ***multisegmental peripheral nerves***. Examples of somatic nerve plexuses are brachial plexus, lumbar plexus and sacral plexus.

> **Dermatomes and Myotomes**
> The uni ateral (one side of the body) area of skin innervated by the sensory fibres of a single spinal nerve is called a ***dermatome***. The unilateral muscle mass innervated by the fibres of a single spinal nerve is called a ***myotome***.

Reflexes and the Reflex Arc

A reflex is a behavioural action. Let us imagine, a pin pricks the forearm of an individual. What does that individual do? He/she immediately, even without consciously thinking of it, pulls the forearm away so as to escape further pin prick This kind of a reaction is called a ***reflex***. Reflexes, therefore, can be defined as rapid, automatic motor responses to stimuli. They are not learned responses; not premeditated upon and are involuntary. Reflexes can be ***somatic*** (muscular contraction, as in the aforesaid example) or ***visceral*** (example—vomiting if any food is not acceptable to the gastrointestinal tract).

From the above, it is easy to understand that there are four steps which take place in a reflex. These four are—(1) stimulus and its reception, (2) information about the stimulus reaching the effector neuron, (3) triggering of action impulse in the effector neuron, and (4) the action potential reaching the effector organ for necessary action. These steps occur in sequential order and certain components are necessary for them to occur. Each of the components activates the one after it. These components are:

- ***Receptor:*** This is the site where the stimulus occurs; in the case of the example cited, it is the forearm or the skin over the forearm;
- ***Sensory neuron:*** This is the neuron whose part will be the peripheral process that receives the stimulus; the peripheral process brings information to the neuronal body and then the same information travels through the central process to the CNS;

- ***Integration centre:*** This is where information from a sensory neuron gets relayed to the motor (effector) neuron; it actually is the synapse;
- ***Motor neuron*:** This is the neuron which sends the efferent impulse to the effector organ;
- ***Effector organ*:** This is the muscle or gland where the required effect is put into action.

All the components go to form a kind of chain; this neuronal chain is called the ***reflex arc***. The receptor, sensory neuron and the presynaptic portion of the synapse together form the ***afferent arm*** (or ***sensory arm***) of the reflex arc and the postsynaptic portion of the synapse, the motor neuron and the effector organ together form the ***efferent arm*** (or ***motor arm***) of the reflex arc.

The simplest of the reflex arcs is the ***monosynaptic reflex arc*** (Fig. 6.14), wherein the sensory neuron directly synapses with the motor neuron. Most of the skeletal muscles of the body are effectively controlled by monosynaptic reflexes. Let us imagine a situation, where an individual is standing for a long time. Some muscles will be contracting and some others relaxing. In prolonged standing, the muscles which have been contracting for a long time develop fatigue and start stretching (losing contraction). The body then begins to sway. Sensory neurons immediately sense the stretching of these muscles and send necessary information. They relay to the motor neurons. The motor neurons trigger necessary action potentials, and thereby, activate the muscles which contract and adjust the body's position. Swaying is stopped and falling down is prevented. The reflexes involved are called the ***stretch reflexes*** and contain only one synapse

Polysynaptic reflexes (Fig. 6.15) are more common. In this type of reflex, one or more interneurons participate

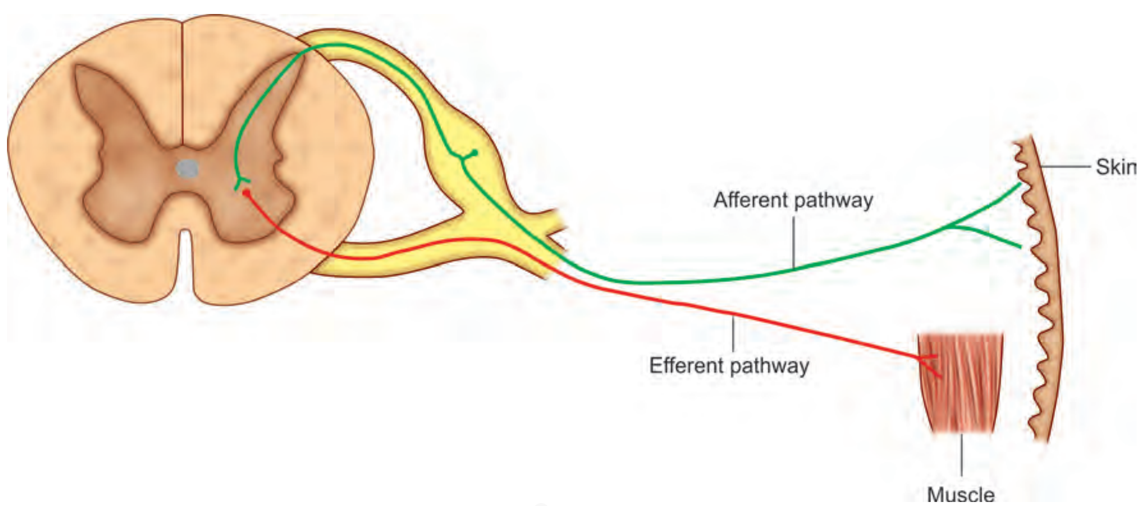


Fig. 6.14: A monosynaptic spinal reflex arc composed of two neurons

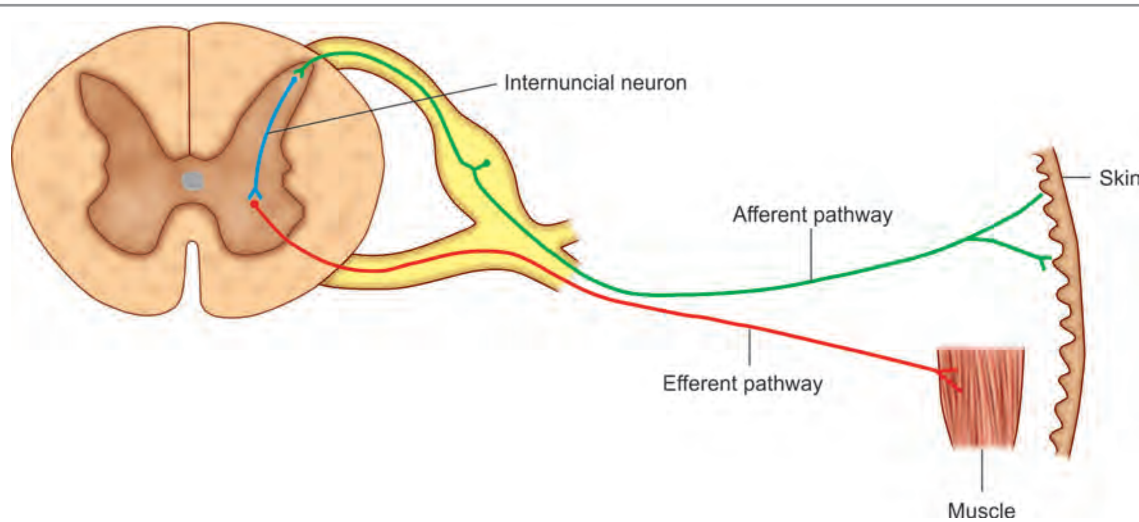


Fig. 6.15: A polysynaptic spinal reflex arc composed of three neurons

in the arc. In a simpler variety of polysynaptic reflexes, the sensory neuron relays to a single in erneuron which in turn relays to the motor neuron. So, a simple reflex arc is usually described to have three participating neurons. Most of the body's ***withdrawal reflexes*** (like the forearm withdrawal in response to a painful stimulus, described above; withdrawal reflexes are those reflexes by which we pull ourselves back from and out of danger) are three neuronal. There are also other polysynaptic reflexes where more number of interneurons participate.

Added Information

- ***Nissl granules*** (Fig 6.16) are clusters of rough endoplasmic reticulum and free ribosomes. These cellular organelles are involved in protein synthesis Therefore, they renew the membranes of the neuron and proteins of the cytoplasm. This function is extremely important since neuronal transmission of impulses is dependent on the membranes of the cell.
- ***Lipofuscin*** is seen more in the neurons of elderly individuals; therefore, is thought to be associated with ageing.
- A group of neurons is called a ***ganglion*** (Greek.ganglio=knot; plural=ganglia). Though earlier groups of neurons both in the CNS and PNS were referred to as ganglia, the term now is restricted to groups of neurons in the PNS only.
- A group of neurons in the CNS is called a ***nucleus***. A bundle of nerve fibres (axons) within the CNS, connecting neighbouring or distant nuclei are called ***tracts***.

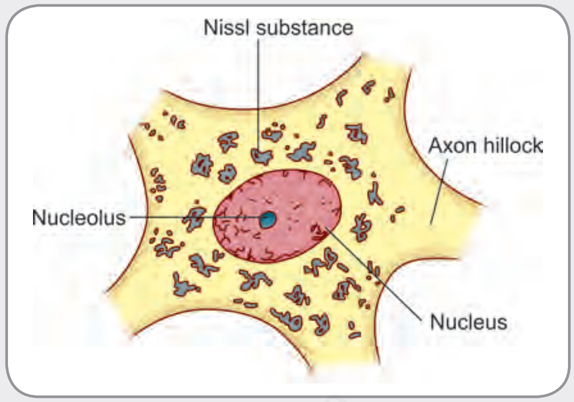


Fig. 6.16: Neuronal cell body shows Nissl substance

- Neurons with long axons have large cell bodies. The cell body through its organelles has to maintain and renew the parts of the axon. The longer the axon, more the cellular organelles required to maintain it. So, to sustain the long axon, the cell body is also large.
- Axons having larger diameters conduct impulses more rapidly than axons with smaller diameters.
- Neurons with more complex dendrons have more synaptic input. In other words, the more the complexity of dendrons, it is possible for more axon terminals to synapse
- Since the astrocytes connect both to the neurons and the capillaries, they are believed to be having a nutritive function. They are thought to transfer nutrients from the capillaries to the neurons. This function, however, is disputed.
- Microglial cells are supposed to be derived from monocytes.
- Since Schwann cells contribute to the neurilemma, they are called the neurilemmocytes.
- In the central nervous system the collections of nerve cells and nerve fibres are called grey matter and white matter respectively. Clusters of nerve cells appear grey in colour. However, when collections of nerve fibres occur, myelin sheaths of the axons make them appear white.

Clinical Correlation

- The supporting cells insulate the nerve fibres. Significance of this insulation can well be understood in conditions where it is absent. Tic douloureux (pronounced tikdoolooroo; French.douloure=painful) is an extremely painful condition. The Schwann cells around the sensory fibres of the trigeminal nerve get degenerated and lost. The insulation of the nerve fibres is also lost. The touch impulses carried in the nerve stimulate the pain fibres, leading to perception of pain even it is mere touch. As a result, the lightest touch to the face causes extreme pain
- In multiple sclerosis, there is generalised loss of myelin. Myelin sheaths gradually disappear. Consequentially, conduction of nerve impulses slows down and ultimately ceases. People affected with this disorder have sensory disorders and weakness of muscles.
- Since neuroglial cells are capable of division, most of the tumours of the brain are gliomas (tumours of glial cells).
- The clinically familiar ***knee jerk*** is an example of a monosynaptic reflex. The ligamentumpatellae is struck; that stretches the quadriceps muscle. Stretching starts an impulse in the sensory neuron, which is relayed to a motor neuron in the spinal cord. The motor neuron sends an impulse for the quadriceps to contract The knee jerk reflex is seen as contraction of quadriceps when the ligamentum patellae is struck.
- Since neurons do not divide and proliferate, those destroyed by damage cannot be replaced. If the axons are damaged but the cell bodies are intact, regeneration may occur and subsequently return of function, too.

Multiple Choice Questions

1. One of the following does not belong to the special somatic afferent system:
   a. Smell
   b. Equilibrium
   c. Hearing
   d. Vibration sense
2. Nissl bodies are:
   a. Lipofuscin granules
   b. Rough endoplasmic reticulum
   c. Nucleolar inclusions
   d. Neurofilaments
3. Neuroglial cells which have cilia are the:
   a. Oligodendrocytes
   b. Microglial cells
   c. Ependymal cells
   d. Astrocytes
4 Spinal nerves are otherwise called:
   a. Segmental nerves
   b. Primary nerves
   c. Somatic nerves
   d. Sensory nerves
5. Withdrawal reflexes of the body are examples of:
   a. Stretch reflexes
   b. Polysynaptic reflexes
   c. Monosynaptic reflexes
   d. Swaying reflexes

ANSWERS

1. d **2.** b **3** c **4.** a **5.** b

Clinical Problem-solving

Case Study 1: A 43 year-old man had severe pain over the left side of his face. Even a slight touch anywhere on the face caused him scream with pain.
- ❑ What condition was he probably suffering from?
- ❑ Why did he experience pain even on mere touch?
- ❑ Which nerve was affected?

Case Study 2: While examining a patient, a neurologist elicited the patient's knee jerk
- ❑ Which muscle is involved in this reflex?
- ❑ What type of reflex is this?
- ❑ Where is the motor neuron situated?

(For solutions see Appendix).

Chapter 7

Blood Vessels and Lymphatics

Frequently Asked Questions

- Classify arteries and give examples of each variety.
- Write a brief note on capillaries and their functions.
- Write notes on (a) Portal system, (b) Lymphatics, (c) Arterio-venous anastomoses, (d) Venae comitantes, (e) Varicosity.
- What are the functions of the lymphatic system?
- What are vena cavae and what is their function?

BLOOD VESSELS

Blood vessels of the body belong to one of the three major types—arteries, veins and capillaries.

Arteries

Blood from the heart is distributed to various parts of the body by ***arteries***. Main and larger arteries branch into smaller arteries which in turn branch into still smaller arterioles. ***Arterioles*** supply blood that is rich in oxygen to capillaries. ***Capillaries*** form a capillary bed. Exchange of oxygen, nutrients and waste products between the capillaries and the extracellular fluid occurs in the capillary bed. From the capillaries, blood drains into venules. ***Venules*** collect into smaller veins which in turn collect into larger ***veins***. The venous blood of the upper parts of the body collect into the ***superior vena cava*** and the venous blood of the lower parts of the body collect into the inferior vena cava; both the vena cavae reach the heart.

Depending upon their properties, arteries are classified into three types, namely the large elastic arteries, the medium muscular arteries and the small arteries.

- Large elastic arteries (also called conducting arteries) have many sheets of elastic fibres in their walls. Because of this, they are able to expand when blood flows into them and return to normal size when the flow is low. They are close to the heart and receive blood under high pressure from the heart. ***Examples*** are the aorta and branches from the arch of aorta.
- Medium muscular arteries (also called distributing arteries) have more smooth muscle fibres in their walls. The smooth muscle fibres may contract and permit reduction in the sizes of their lumina (singular lumen), thus regulating blood flow to different parts of the body as required by circumstances. This reduction is called vasoconstriction. ***Examples*** of medium muscular arteries are brachial artery, radial artery, femoral artery and profundafemoris artery.
- Small arteries have thick muscular walls and narrow lumina.

Branches of an artery communicate with each other and branches of adjacent arteries. These communications are called ***anastomoses*** (singular, anastomosis). If a main artery is blocked gradually, blood flow increases in the anastomoses and forms an alternate route. ***Collateral circulation*** is thereby established and blood supply to structures distal to the blockage is restored. Collateral channels can open only if adequate period of time is available. If the blockage or occlusion is sudden, collaterals are insufficient.

Arteries which do not anastomose with adjacent arteries are called ***end arteries*** or ***true terminal arteries***. If such an artery is occluded, the structure supplied by it is deprived of blood supply. Retina is supplied by true terminal arteries Though not anatomic end arteries, **functional terminal arteries** also exist. They have ineffective anastomoses. Such arteries supply parts of brain, kidneys, intestines, spleen and heart.

Veins

Veins carry blood to the heart. Like the arteries, veins also have three types—small veins or ***venules***, ***medium veins*** and ***large veins***.

- Venules drain capillary beds and unite with other venules to form small veins. ***Small veins*** unite to form slightly larger veins which usually form the venous plexuses. Though we describe this type in separate units for convenience, all of them are basically the same with regard to their properties.

Dissection

As you dissect vessels of considerable size, try to hold the vessel and feel it between your thumb and fingers. You will be able to understand that a vessel has a lumen because your fingers will sway up and down. As an artery is compressed between the fingers, you can feel its recoil in the next few seconds. A vein has no such feel and gets compressed almost completely. Compressing a vein may not be possible when the blood in it is clotted (often seen in cadavers); but the thin nature of its wall can be made out in most cases.

- ***Medium veins*** drain venous plexuses and accompany medium arteries. They have venous valves which permit unidirectional blood flow towards the heart. ***Examples*** of medium veins are the cephalic vein, the basilica vein, the saphenous veins and the various veins which are named according to the arteries they accompany like the femoral vein.
- ***Large veins*** have bundles of longitudinal smooth muscles in their walls. Superior vena cava is an ***example***.

Deep arteries are usually accompanied by not a single vein but by a pair of veins. These are the ***venae comitantes***. The two (rarely, more than two) venae comitantes communicate with each other by means of cross channels. By this arrangement, a counter-current heating system is established. The blood returning from various parts of the body in the veins is cooler and the blood flowing in the arteries is warmer. The close proximity of venae comitantes and the cross channels to the artery allows the cooler blood to be warmed as it returns to the heart. The venae comitantes, along with the artery are usually enclosed in a vascular sheath, which is not very yielding. When blood flows through the artery in such a system, the artery expands and compresses the veins. The veins, though expandable due to the restriction posed by the sheath, are stretched and flattened. This aids in pushing the blood up the veins, facilitating venous return

Histology

The walls of all blood vessels (except the smallest) have three layers called the tunics (Latin.tunikah=coat). The tunics surround the blood-filled space called the lumen. From interior to exterior these tunics are the tunica intima, tunica media and tunica adventitia (Fig. 7.1).

- ***Tunica intima*** (Latin.intimus=innermost)—layer in contact with blood; contains endothelium, which is a layer of simple squamous epithelium that lines the lumen; the slick surface of endothelium minimizes the friction of blood flow; in larger vessels, a layer of connective tissue called the subendothelial tissue lies outer to the endothelium.
- ***Tunica media*** (Latin.medius=middle)—middle layer which has circularly placed smooth muscle cells and elastin fibres; contraction of these smooth muscle cells causes narrowing of the lumen called vasoconstriction;

contd...

Histology *contd...*

relaxation of the same cells increases the luminal size (vasodilatation); in arteries this layer is bulky because both constriction-dilatation mechanics and elasticity have great functional importance.

- ***Tunica adventitia*** (Latin.adventicius=coming from elsewhere)—outermost layer that has connective tissue which protects the vessel; the connective tissue cells and fibres in this layer run longitudinally and help anchor the vessel to the surrounding structures; this layer also strengthens the vessel wall.

In the tunica adventitia of large vessels are found small vessels which supply the outer portion of the vessel wall. These are the ***vasa vasorum*** (vessels of vessels; Latin.vas=vessel). The inner portion of the vessel walls of large vessels and complete vessel walls of smaller vessels derive their nourishment from the luminal blood itself. Vasa vasorum may be branches of the same parent vessel or adjacent vessels.

The walls of veins are thinner than those of arteries and the lumina are larger. The tunica adventitia is thicker than the tunica media; and elastin is much less. In addition, the tunica intima folds on itself to form venous valves; these valves ensure unidirectional flow of blood, i.e., towards the heart.

Capillaries

Capillaries are connection tubes between the arterioles and the venules. They form a network called the capillary bed. Exchange of material between the blood in the capillaries and the extracellular fluid takes place in the capillary bed.

At the arterial end of the capillary bed (referred to as the upstream) oxygen, nutrients and other material are pushed out of the capillary due to higher pressure of blood. But capillary walls (Fig. 7 2) are relatively impermeable to proteins. At the venous end of the capillary bed (referred to as downstream), waste products and carbon dioxide are to be reabsorbed. This reabsorption occurs as a result of osmotic pressure from higher concentrations of proteins within the capillaries. This mechanism is sometimes referred to as the 'Starling hypothesis'.

Histology

The wall of a capillary has a single layer of endothe ium surrounded by a basal lamina. The cells of endothelim are connected to each other by tight junctions. The gaps in between such junctions are called intercellular clefts and serve as passages from and to the blood in the capillary.

Capillaries may be of two types, namely ***fenestrated*** and ***continuous***.

- ***Fenestrated capillaries*** (Fig. 7.3)—There are pores (fenestrations, latin.fenestrum = window) piercing the endothelial cells. Exchange of molecules occurs through these fenestrations; wherever exchange is high, fenestrated capillaries are more; examples are capillaries in the small intestine and synovial joints.
- ***Continuous capillaries*** (Fig. 7.4)—These have no fenestrations and are found in skeletal muscles, skin, CNS and majority of organs.

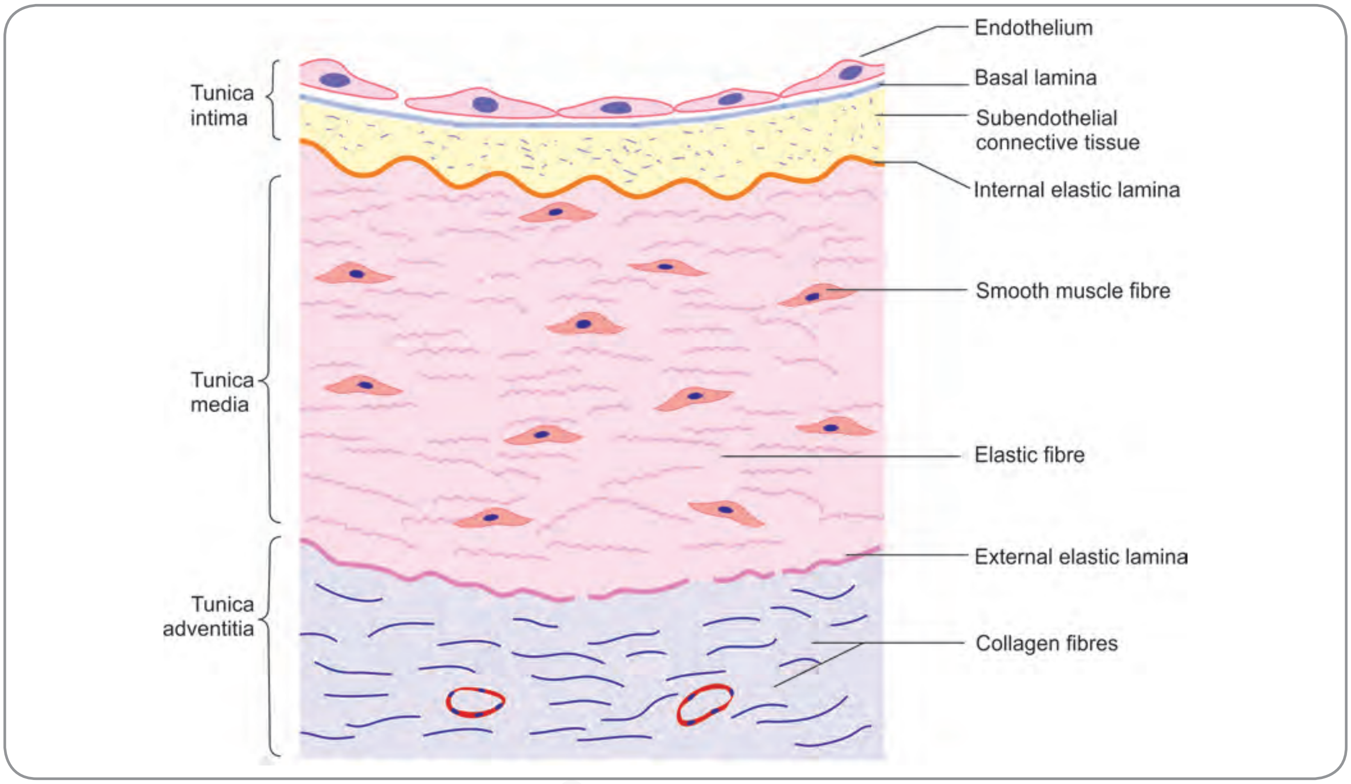


Fig. 7.1: Layers in the wall of a typical artery

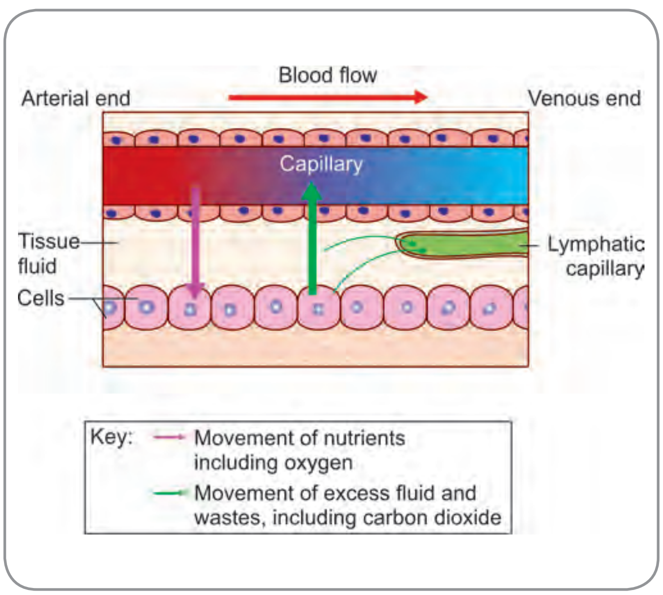


Fig. 7.2: A capillary and its relation to a lymphatic capillary

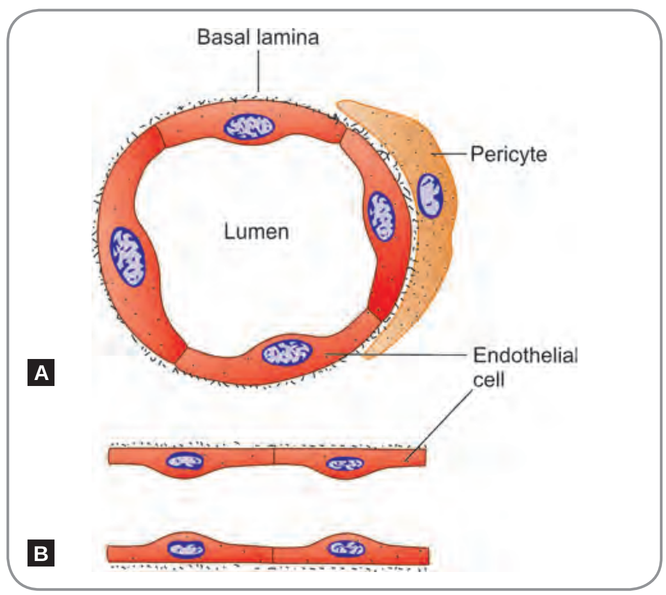


Fig. 7.3: Structure of continuous capillary **A.** Circular section **B.** Longitudinal section

Arteriovenous Anastomoses

In some parts of the body, the arterioles and venules which supply and drain the capillary bed, are also directly connected proximal to the capillary bed. This permits direct shunting of blood from the arterioles to the venules without going through the capillaries. Such arteriolovenular (arteriovenous) shunts are seen more in skin and in peripheral parts like the fingers. When the body has to conserve heat, blood does not go to the capillary bed and shunts through the arteriolovenular anastomoses (Fig. 7 5).

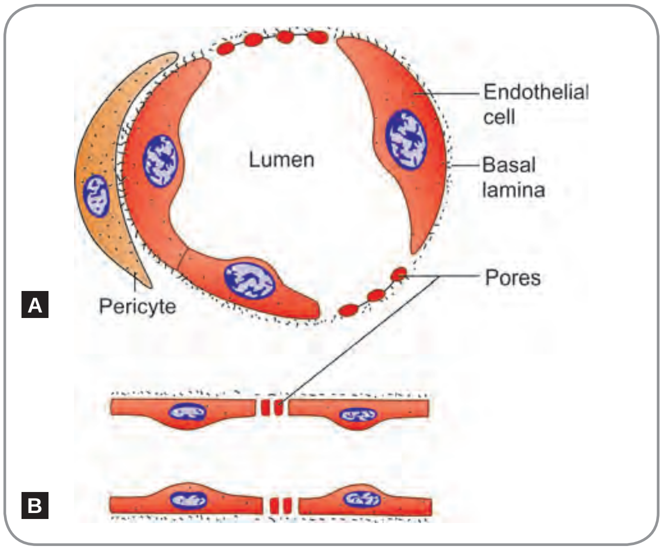


Fig. 7.4: Structure of fenestrated capillary **A.** Circular section **B.** Longitudinal section

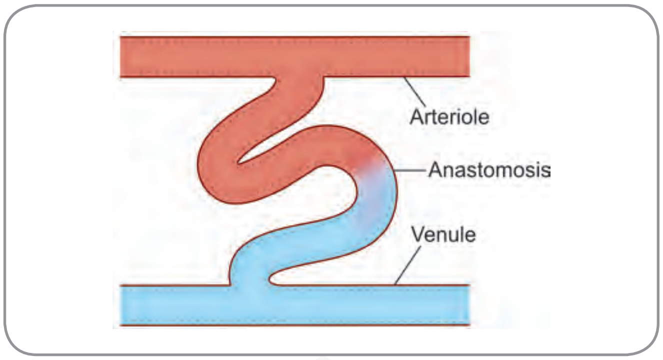


Fig. 7.5: Schematic representation of arteriovenous anastomosis

Portal Venous System

Sometimes, blood passes through two capillary beds before reaching the heart. In such cases, the two capillary beds are connected by a venous system and this venous system is called a portal system. In a well-known example, blood from the capillary bed of the intestines reaches the capillary bed of the liver. The venous system connecting the two is the hepatic portal system.

LYMPHATICS

Lymphatics belong to what is called the lymphatic system (or the lymphoid system). We have already seen that most of the substances getting filtered at the arterial end of the capillary bed also get reabsorbed at the venous end. However, this amount of reabsorption is not sufficient even on a daily basis. As much as 3 litres of fluid is left to be reabsorbed in the extracellular spaces of the body everyday. In addition, some proteins leak into the extracellular spaces. Further, some more material which cannot enter the capillary bed gets accumulated in the extracellular area. If all this is left behind, it would lead to a dangerous situation. Reverse osmosis would occur and more fluid would flow into the already loaded extracellular space causing oedema (excessive interstitial fluid).

In normal life, the fluid balance is well maintained, amount of interstitial fluid remains fairly constant and unwanted material does not accumulate in the extracellular space. All these proper balances are possible due to the action of the lymphatics and the lymphatic system.

The system acts in the following sequence:

- Extensive networks of thin lymphatic capillaries occur in the extracellular spaces. These are the lympha ic plexuses and drain surplus tissue fluid, proteins, bacteria, debris and all that which accumulates in the spaces.

As compared to blood capillaries, much larger molecules can pass through the walls of lymph capillaries. These include colloidal material, fat droplets, and particulate matter such as bacteria. It is believed that these substances pass into lymph capillaries through gaps between endothelial cells lining the capillary; or by pinocytosis.

Lymph capillaries are present in most tissues of body. They are absent in avascular tissues (e.g., the cornea, hair, nails); in the splenic pulp; and in the bone marrow. It has been held that lymphatics are not present in nervous tissue, but we now know that some vessels are present.

- Lymphatic vessels are formed from the lymphatic plexuses and drain them. These vessels have valves and so have a beaded appearance. Lymphatic vessels are found in all parts of the body except the teeth, bone, bone marrow and brain.
- Lymph, the fluid that flows through the lymphatic capillaries and vessels, is filtered by the lymph nodes which occur along the course of the lymphatics.
- As the lymphatic vessels run proximally, they merge and become larger. Larger lymph vessels drain into lymphatic trunks which ultimately unite to form the right lymphatic duct on the right side and the thoracic duct on the left side.

The right lymphatic duct drains lymph from the right side of head, neck and thorax and the right upper limb. It enters the venous system at the junction of the right internal jugular and the right subclavian veins. The thoracic duct drains lymph from the rest of the body. The lymphatics collecting lymph from the lower parts of the body merge in the abdomen to form the cistern chyli. From this starts the thoracic duct, which ascends up to enter the venous system at the junction of the left internal jugular vein and the left subclavian vein.

Apart from helping in proper fluid and solvent balance of the body, the lymphatic system also has other functions.

Special lymphatic capillaries called the lacteals receive the lipids and lipid-soluble vitamins absorbed in the intestines. The milky fluid thus formed is conveyed by visceral lymphatics to the cistern chyli and the thoracic duct.

When foreign protein or foreign material drains from an area, the lymph nodes filter them and attempt to eliminate them from the body. Also, antibodies (molecules to fight the foreign substance) are produced by the lymphatic system

Added Information

- Arterioles are the smallest arteries.
- ***Capillary permeability*** means ability of transport of material through capillaries. Such transport occurs through four channels: (1) Intercellular clefts, (2) Fenestrations, (3) Cytoplasmic vesicles, and (4) Direct diffusion. Transport of small molecules is through the intercellular clefts; larger molecules are transported by fenestrations and by cytoplasmic vesicles, which undergo endocytosis and exocytosis, as required. Direct diffusion is the process by which the substances pass through the membranes of the endoplasmic cell Oxygen and carbon dioxide are important substances transported by diffusion.
- A ***sinusoid*** (also called ***sinusoidal capillaries***) can be described as a specialised capilla y It has both expanded and narrowed areas Its walls are fenestrated; tight junctions fewer in number; intercellular clefts wider Thus, sinusoids help in extensive exchange and are, therefore, found in regions where transport of more and large-sized material occurs. Examples are sinusoids in bone marrow, liver and spleen.
- The structure of a ***capillary bed*** is well adapted to its functions. (Traced from the arterial end) A small arteriole leads to a ***metarteriole***; this is a vessel which is intermediary between the arteriole and the capillary. Capillaries branch off from the metarteriole. The metarteriole itself however continues as a ***thoroughfare channel***, which is an intermediary vessel between the capillary and the venule. The thoroughfare channel joins a ***venule***. The capillaries which are given out by the metarteriole branch and unite to form a meshwork and the emerging capillaries from this mesh drain into the venule. A smooth muscle cell winds around the root of each capillary branching off the metarteriole; this forms the ***precapillary sphincter***. When the sphincters are open (relaxed), blood flows through the capillaries and the surrounding tissue is well supplied. When the sphincters are closed (contracted), blood flows through the metarteriole-thoroughfare channel-venule pathway bypassing the capillary bed. The sphincters open when the tissue needs blood and close when tissue needs are minimal.
- Venous valves are abundant in the veins of lower limbs; less in veins of head and neck not present in thoracic and abdominal veins. When venous valves (especially those in the lower limb veins) weaken, blood return is jeopardised. Venous drainage itself is slow and large quantities of blood get pooled in veins. When veins are so engorged, they are called ***varicose veins*** and the condition is varicosity; the veins usually have a 'beaded' appearance (engorgement more in the parts between valves and the area of valves causing constrictions) Varicose veins are more common in women and in individuals who are predisposed to long hours of standing (shop assistants, nurses and even surgeons). Conditions like obesity, pregnancy and those of increased intra-abdominal pressure aggravate the problem. Increased intra-abdominal pressure may obstruct venous return from the regions of rectum and anal canal leading to varicosities in the veins of anal canal. This condition is called ***piles*** or ***haemorrhoids***.

Clinical Correlation

- ***Arteriosclerosis*** is a group of diseases of arteries where there is thickening of the walls and loss of elasticity. Atherosclerosis is the most common form of arteriosclerosis. Initially fat, mainly cholesterol, builds up in the walls of the arteries. Calcium gets deposited in these sites and an atheromatous plaque is thus formed. These plaques are hardened swellings on the internal surface of the walls and cause narrowing of the lumen. Blood supply to the concerned structure or organ is reduced. As blood tends to flow through the narrowed lumen, there is slowing and stagnation. Blood then clots leading to intravascular clot formation. This s called thrombosis. The resultant thrombus occludes the artery. Sometimes, the th ombus or a part of it may break away and travel in the blood stream. Such a travelling bolus is called an embolus. An embolus can block smaller vessels distally.
- Loss of blood supply to a structure or organ can cause ***ischaemia*** (reduced blood supply) or infarction (death of tissue due to lack of blood supply).
- When discussing cancer, surgeons usually discuss ***lymph nodal involvement***. How do lymph nodes get involved with cancer? Several cancers spread by the lymphogenous route. Cancer cells loosened from the site of cancer enter the lymphatics. They are filtered and trapped by the lymph nodes, which thus become secondary sites of cancer.
- ***Lymphangitis*** is inflammation of lymph vesels; ***lymphadenitis*** is inflammation of lymph nodes. When lymph does not drain from a particular area, there is localized oedema called ***lymphoedema***.

Multiple Choice Questions

1. Examples of distributing arteries include all of the following except:
   a. Brachial artery
   b. Radial artery
   c. Aorta
   d. Femoral artery
2. The cross channels of venae comitantes establish:
   a. A counter-current heating system
   b. A faster venous return
   c. A direct shunt from arteries
   d. A rapid gas exchange
3. When the body tends to conserve heat, blood goes through the:
   a. Capillary bed
   b. Arteriolovenular anastomosis
   c. End arteries
   d. Portal system
4. Lymphatic vessels:
   a. Drain lymphatic plexuses
   b. Have no valves
   c. Are abundant in the teeth
   d. Branch from capillaries
5. The thoracic duct:
   a. Continues as the right lymphatic duct
   b. Enters into the venous system
   c. Drains head and neck
   d. Is an arteriovenous shunt

ANSWERS

1. c **2.** a **3.** b **4.** a **5.** b

Clinical Problem-solving

Case Study 1: A 54-year-old man complained of chest pain. The doctor informed him that his heart was suffering from reduced blood supply.
- What is the term for reduced blood supply?
- What is the common cause for reduction of blood supply that acts by reducing the lumina of blood vessels?
- What is the condition where there is intravascular blood clot?

Case Study 2: A 63-year-old man who had worked as a sales assistant complained of beaded veins in his left lower limb.
- Can you identify the problem?
- Why do the veins appear beaded?
- What structures are at fault?

(For solutions see Appendix).

Chapter 8

Introduction to Clinical Anatomy

Frequently Asked Questions

- Write notes on (a) Inflammation, (b) Dislocation of a joint, (c) Sarcoma, (d) Green stick fracture, (e) Sprain of a ligament.
- Describe the process of fracture healing.
- What is collateral circulation and what is its importance?
- Differentiate between a primary and a secondary tumour.
- Give the terms for the following: (a) Common cold, (b) Inflammation of stomach, (c) Inflammation of lymph vessels, (d) Tearing of a muscle, (e) Harmful tumours.

The body and its various parts can get affected by several disorders or diseases. It is good to know a few things about these conditions and the terms related to them. Knowledge of Anatomy has to be applied clinically; many of the disorders and diseases can better be understood by knowledge of anatomy.

INJURY

The effects of injury will depend on the tissues injured, and on the severity of injury.

Injuries to Bones

Injury to a bone can break it; such a condition is called a ***fracture***. The line along which a bone fractures may be ***transverse***, ***oblique***, or ***spiral***. A fracture in which a bone breaks into several small pieces is called a ***comminuted fracture***. Sometimes a bone, made up mainly of cancellous bone, (e.g., body of a vertebra) may be compressed; such a fracture is called a ***compression fracture***.

In young children, with soft bones, fractures are often incomplete (i.e , the two parts of a fractured bone remain together) These are referred to as ***green-stick fractures***.

The two fragments of a fractured long bone may sometimes retain their normal relative position, but quite commonly the fragments move away from their original locations. This is called ***displacement***. Displacement is produced by the actions of muscles on the two fragments.

In treating a fracture, the surgeon tries to bring the fragments back to their normal relative position. This is called ***reduction*** of the fracture. Thereafter, measures are taken to prevent the fragments from being displaced again. So, the parts concerned are prevented from moving; ***immobilisation*** is effected. Immobilisation can be done by applying a suitable ***plaster cast*** around the limb, or by operation in which the two fragments are united using metal appliances of various types (***internal fixation*** and ***external fixation***). Immobilisation aids the process of healing, and relieves pain.

Process of Fracture Healing

Immediately after a fracture, there is bleeding from vessels within the bone. This collection of blood called ***haematoma,*** surrounds the site of the fracture. The bone itself contains cells that help in repair. These cells proliferate and invade the haematoma. Cells growing out of the two pieces of bone meet to form a single mass of cells. New bone is formed within the mass. This bone forms a covering for the adjacent ends of the two bone pieces and unites them. This covering is called the ***callus.*** (Greek Callus=horn; though this term is derived from the same source and because of the same reason of hardness, it has to be differentiated from the callus of skin). Immature bone of the callus is gradually replaced by mature bone. In this way, the bone becomes united once again, but the region of the fracture is thick and may be irregular. As the newly formed bone becomes strong, excess bone around the fracture site is gradually removed. This is called ***remodelling***. Following remodelling in the bones of children, no trace of the fracture site may remain

However, in adults, the fracture site usually shows a recognisable irregularity.

Injuries to Joints and Ligaments

Severe injury can result in separation of the bones taking part in a joint. This is called ***dislocation***.

Dislocation is more likely to occur in joints that allow free movement e.g , the shoulder joint. Dislocation usually involves damage to the capsule and to some ligaments. In some cases, the two articular surfaces are displaced from their normal position but retain some contact with each other. This condition is called ***subluxation***. When dislocation at a joint is combined with fracture of one of the bones within the joint, the condition is called ***fracture-dislocation***.

A force that strongly stretches a ligament can cause its rupture. This usually leads to displacement of the joint surfaces. However, injury to a ligament short of rupture can be a cause of serious pain at a joint, especially during movements which tend to stretch the ligament. Such a condition is referred to as ***sprain*** (to be differentiated from *strain* which is injury to a muscle). Ligaments can also be damaged by prolonged mild stress.

Injuries to Blood Vessels

Injury to an artery is dangerous because the consequential loss of blood, if unchecked, can lead to death. Bleeding from an artery can be stopped by applying pressure over a suitable point. Knowledge of points where major arteries can be palpated and pressure applied on them is therefore of great importance.

Injuries to large veins can also be serious. In some veins, the pressure can be lower than atmospheric pressure and air can be sucked into them.This air travels into the heart and lungs and can block small vessels and capillaries there. This condition is called ***air embolism***.

Injured vessels have to be ***ligated*** (tied up). In the case of large vessels, repair of the vessel is possible. Ligation of an artery carries the risk of necrosis (death) of the part supplied if its blood supply through alternative channels (***collateral circulation***) is not adequate. For this reason, knowledge of anastomoses established by various arteries becomes important. Anastomoses are most abundant in regions where the main artery is subjected to compression because of movements e.g., around joints.

Injuries to Nerves

Injuries to nerves, if complete, can lead to ***paralysis*** (loss of the power of movement) of all muscles supplied and ***anaesthesia*** (loss of sensations) over the area of sensory supply. When a nerve is injured, all structures supplied by branches arising distal to the point of njury are affected. However, injury may be partial and only some of the structures are then affected.

The extent of sensory loss is usually less than the area supplied by the nerve, because of overlap in the territories supplied by adjoining cutaneous nerves.

Injuries to Other Tissues

A ***muscle*** may be injured by any kind of direct violence. It may also be injured during rigorous exercise (as in athletes). In persons having sedentary occupations, and in old age, even mild unaccustomed movement can lead to strain within a muscle leading to pain and discomfort (strain is tearing of a muscle, often due to sudden movement that over stretches it; bleeding occurs within the bulk of the muscle).

However, the most serious effects on muscles are seen following injury to the nerves supplying them. Muscles can also be paralysed as a result of injury to the brain, the spinal cord, or to nerve roots.

Tendons can be injured as a result of injury. A sharp injury can cut right through a tendon. A tendon can be damaged by a fractured bone. A tendon weakened by degenerative changes may rupture with relatively mild force.

Skin is the tissue most commonly affected by injury. However, because of great regenerative capacity, superficial injuries are easily repaired. When large areas of skin are lost, these areas can be covered with skin taken from other parts of the body. Such a process is called ***skin grafting*** Injury to skin may also be caused by extreme heat (burns), or by extreme cold; by chemicals (e.g., strong acids or alkalis); electrical currents; and by various kinds of radiations. Large areas of skin can be lost as a result of burns. In such cases, death can occur because of loss of large amount of water from the body or because of infection.

Injuries to ***internal organs*** are usually serious and require urgent surgery An injured organ may bleed into a body cavity. Such an ***internal haemorrhage*** can lead to death if it is not recognised and treated in time.

Injury to the brain is always very serious and often a cause of death. Damaged nerve cells cannot regenerate and if the patient survives some effects of injury may persist.

INFLAMMATION AND INFECTIONS

Any tissue or organ in the body can be infected with microorganisms. These microorganisms usually are bacteria or viruses. Infection may be acute (immediate) or chronic (long-drawn)

In an acute infection, the affected tissue usually shows signs of ***nflammation***. The affected part becomes

warm and red in colour because of greater blood flow. Accumulation of fluid causes swelling; and pressure on nerves in the area causes pain.

Infection can lead to pus formation. If the pus is in an enclosed space (as on the tip of a finger) it can cause considerable pain. Infection often spreads along fascial planes. Its spread can be limited by fascial septa (as in the palm). In the treatment of infections, knowledge of the anatomy of the part is, therefore, important.

Inflammation of a particular part is indicated by a term that is formed by the name of the part followed by the suffix 'itis' (Greek.itis=inflammation). Inflammation of the tonsil is ***tonsillitis***. Inflammation of the vermiform appendix is called ***appendicitis***. Inflammation of the mucosa of stomach is ***gastritis.***

Since conditions like tonsillitis and appendicitis are usually caused by infections, it is customary to use the related terms for infective diseases of tonsils and appendix. In other organs, inflammation can be caused by agents other than infection. For example, gastritis can be caused by any substance that irritates it (e.g. alcohol or a drug).

Common cold (***rhinitis***) can result from a virus infection, but it can also be caused by ***allergy*** (undue sensitivity of the tissue to some foreign substance). Inflammation can also be caused by physical agents like heat, cold, mechanical trauma and radiations.

When there is infection in any part of the body, lymph nodes draining area may enlarge and become painful. This condition is called ***lymphadenitis***. Lymph vessels may also get inflamed (***lymphangitis***) and may be seen as red streaks over the skin.

NEOPLASIA

Cancer is a dreaded disease. What is cancer and how does it happen?

Within the body, cells of various tissues are constantly multiplying to replace dead cells. The rate of multiplication varies from tissue to tissue and is controlled by natural mechanisms of the body. Under certain circumstances the mechanisms that control cell proliferation do not work. As a result, there can be uncontrolled multiplication of cells leading to the formation of a ***neoplasm*** (Greek.Neas, neo=new, plasm=anything formed) or ***tumour*** (Latin. Tumour=swelling).

Some tumours remain confined to their original site and do not cause any harm. Such tumours are said to be ***benign*** (Latin.benignus=kind) and their surgical removal leads to complete cure. In the case of other tumours, some cells that get detached from the main tumour, spread to distant sites (either through lymphatic vessels or through veins) and start multiplying forming new tumours. Such tumours are said to be ***malignant*** (harmful, Latin. malign= to do bad, harmful); these are the ones usually referred to as 'cancer'. When spread occurs, the original tumour is the ***primary tumour***, while the ones formed by spread from it are called ***secondaries*** (or secondary tumours). The spread of malignant tumours greatly adds to the difficulty of treating them, and once secondaries form, complete eradication of the tumour may become impossible. A malignant growth arising from epithelial cells is called a ***carcinoma*** (Greek.karcinos=cancer, oma=swelling). Carcinoma can arise in the skin, in any tube or cavity lined with epithelium, and from epithelia of glands.A malignant tumour arising from non-epithelial tissue is usually referred to as ***sarcoma*** (Greek.sarx=flesh, sarcoma= fleshy swelling). Such tumours can arise from connective tissue (***fibrosarcoma***), from muscle (***myosarcoma***) and from bone (***osteosarcoma***).

OTHER CAUSES OF DISEASE

Apart from trauma, inflammation due to various causes and neoplasms, there are also other causes that lead to diseases.

- An individual may be born with physical defects that may affect the exterior or interior of the body. Such defects are called ***congenital malformations***. These occur as a result of incomplete or abnormal development.
- Many diseases can be traced to genetic causes. Genetic defects can result in biochemical alterations that can lead to various ***genetic disorders***.
- Diseases can also be produced as a result of ***malnutrition (nutritional disorders)***.
- Diseases can be caused as a result of normal ageing processes. With increasing age there is narrowing of the arteries. Lack of adequate blood supply to the heart or to the brain can lead to serious consequences. Wear and tear in joints is a common cause of joint pains in old persons. Degenerative joint disease including osteoarthritis can occur.

Multiple Choice Questions

1. A fracture where the bone breaks into several pieces is:
   a. Transverse fracture
   b. Compression fracture
   c. Green stick fracture
   d. Comminuted fracture
2. Anastomoses are more in areas where arteries are prone to:
   a. Compression
   b. Collateral circulation
   c. Thrombosis
   d. Injuries
3. The red colour in an area of inflammation is due to:
   a. Increased blood flow
   b. Pressure on nerves
   c. Pus formation
   d. Fluid accumulation
4. Uncontrolled multiplication of cells leads to
   a. Neoplasm
   b. Embolism
   c. Lymphadenitis
   d. Malnutrition
5. Subluxation is a type of:
   a. Bony fracture
   b. Joint dislocation
   c. Bone remodelling
   d. Nerve damage

ANSWERS

1. d **2.** a **3** a **4.** a **5.** b

Clinical Problem-solving

Case Study 1: A 12-year-old boy accidentally poured a bottle of acid on himself. His physician after giving treatment also told him to drink a lot of fluids.

- Can you suggest what kind of injury would this boy have suffered?
- If the boy had sustained an extensive damage what procedure would the physician have thought of?
- Why did the physician advocate increased fluid intake?

Case Study 2: A 72-year-old sick man was told that he has carcinoma and it has also spread to other areas.

- Can you suggest what kind of problem does this man have from the term ‘carcinoma’?
- How can the ‘spread’ be otherwise called?
- What name is given to harmless growths?

(For solutions see Appendix).

Chapter 9

Introduction to Radiological Anatomy

Frequently Asked Questions

- Write briefly on Radiography.
- Expand: (a) CAT scan, (b) PET scan, (c) MRI.
- What is the principle involved in ultrasonography?
- Write notes on (a) Medical imaging, (b) Digital subtraction angiography (c) Contrast X-rays, (d) Fluoroscopy, (e) Radio opaque structures.

In November 1895, Wilhelm Conrad Roentgen discovered some waves belonging to the spectrum of electromagnetic radiation and called them X-rays despite not knowing all their properties at that point of time. The method of obtaining X-ray shadow pictures has subsequently been utilized in medical diagnostics. Since the emission of X-rays is a form of radiation, the science of X-rays has been termed as 'Radiology' and X-ray pictures are called radiographs (Greek.graphos=writing).

The object to be 'pictured' or visualized is placed in the path of X-rays; shadows are cast and these form the X-ray images. Since X-ray shadows are invisible to the human eye, X-ray images are either viewed on fluorescent screens or made permanent with photographic procedures. The X-ray beam is made to go through the object to be radiographed; in diagnostic X-rays, the entire human body or a part of it which has to be analyzed is the 'object'. The radiographic film is placed on the other side and the shadow cast by the object is captured.

Radio-opaque (the two terms 'radio' and 'opaque' have been merged, and for convenience sake, a new single word 'radiopaque' has been formed) objects cause complete shadows. Objects which are partially radiopaque and partially radiolucent cast intermediary shadows. Due to their calcium content, bones are highly radiopaque and produce conspicuous X-ray images. Images produced by soft tissues and fat are not very clear. Air and all gases are virtually radiolucent.

READING OF AN X-RAY PICTURE

In the X-ray pictures (the pictures which appear blackish and like photographic negatives) which we hold and study, the X-ray image has been caught on films using photographic procedures.

The picture should always be held as though the concerned individual is standing in front of the X-ray examiner Thus, left of the X-ray picture is on the right of the examiner and vice-versa.

The first step is to identify the area or region that has been radiographed, preferably with the 'specific view'. In X-ray, views indicate the X-ray beam direction. The 'view' is generally given by a term which has two parts; the first part is related to the source of the X-ray and the second part is related to the placement of the radiographic film. Let us understand the use of such terms with an example. Chest X-rays are usually taken with posteroanterior (PA) views (Fig. 9.1). In such instances, the individual stands with his/her anterior chest wall close to the radiographic film X-ray source is on the posterior aspect of the individual. When X-ray beam is sent, the direction is from posterior to anterior (parts of the chest which is being radiographed). So, the view is posteroanterior or 'PA' for short. Different parts of the body and various disorders require different beam directions. Posteroanterior, anteroposterior, lateral (Fig. 9.2) and oblique views are usually taken.

The second step is to state whether the X-ray picture is a plain radiograph or a special radiograph. Then, the details of the radiograph are studied. White or light areas are dense structures like bone; these are radiopaque. Darker areas are soft tissues or organs which are radiolucent.

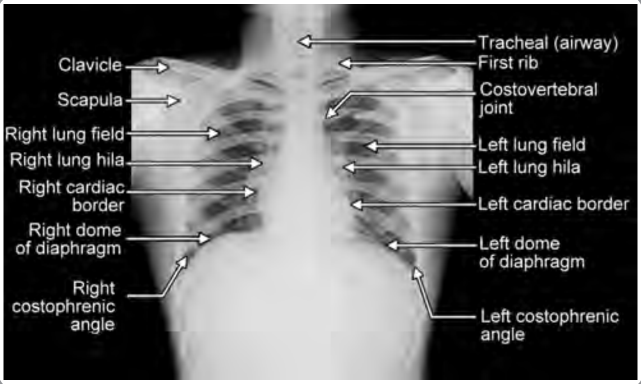


Fig. 9.1: Chest X-ray (posteroanterior view)

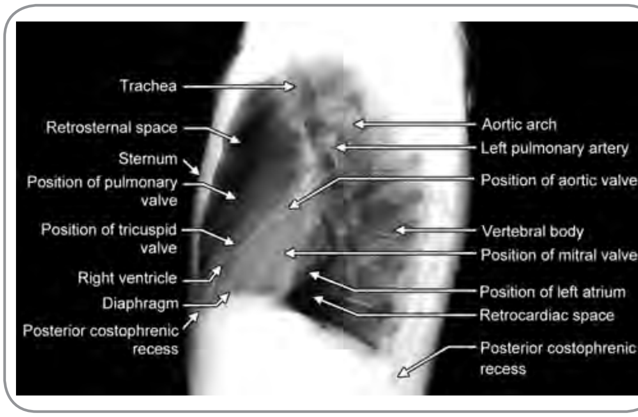


Fig 9 2: Chest X-ray (lateral view)

X-rays are best for visualizing bones and dense structures such as tuberculous lymph nodes.

Special Radiographs

In plain X-ray pictures, radiopaque structures produce dense and conspicuous shadows. However, most of body's tissues are heterogenous in composition; so, they are partially radiopaque and partially radiolucent. Shadows are, therefore, intermediary in nature. It is practically not possible to distinguish between the shadow produced by different types of soft tissues, like muscles, connective tissue and vessels. In diseased conditions, many of the different types of soft tissues are adherent to each other and the x-ray picture may not add any information.

To visualise special situations and varied tissues, specialised radiological techniques have been devised.

- ***Fluoroscopy:*** Part of the human body is positioned under a fluorescent screen and the images viewed live. Moving structures or movement-oriented studies are done through fluoroscopy. Examples are process of swallowing and passage of contrast material within organs Swallowing is a process and a 'still' picture may not reveal much with regard to disorders of swallowing. Similarly, when a contrast material is made to pass through the gastrointestinal tract, the movements of it can be monitored. Fluoroscopy is usually employed in functional tests and in studying blood flow through vessels.
- ***Cineradiography:*** It is a method where the X-ray is recorded in a cinema film.
- ***Contrast radiography:*** As already seen, it is not possible to visualise hollow structures in plain radiographs Various disorders of vessels and gastrointestinal tract occur and it is essential to know what has gone wrong with such structures. A non-toxic radiopaque substance (usually a salt like barium sulphate) is used to fill the hollow organ so that an X-ray picture will show the contour of the organ. Sometimes, the salt is made to form a thin film over the inner surface of the organ concerned, thus giving a clear picture of the contour of the surface (ups and downs, new growths or swellings on the surface, ulcerations, etc.). Barium meal study is used to visualize upper gastrointestinal organs like the stomach and duodenum; barium enema is used for lower gastrointestinal organs like the colon; barium swallow is used for visualizing the oesophagus.

Suitable contrast material are used to study blood vessels (angiography), arteries (arteriography), lymphatic vessels (lymphangiography), lymph nodes (lymphadenography), the calyces and the pelvis of kidney (pyelography), ureters (ureterography), urinary bladder (cystography), gall bladder (cholecystography), uterus and fallopian tubes (hysterosalpingography), meningeal spaces of spinal cord (myelography) and the bronchial tree (bronchography). Photographically recorded pictures of such procedures are usually referred to by the term 'gram' (Greek.gramme = mark) suffixed to the area visualised. Thus, we have angiograms, arteriograms, lymphangiogram and lymphadenopathy, pyelograms and ureterograms, cystograms, cholecystograms, myelograms and bronchograms.

Newer Techniques of Internal Visualisation

In plain X-rays, two major disadvantages are seen. Firstly, soft tissue images are blurred; secondly, only a two-dimensional image is obtained. When there is a denser structure, it obscures a less dense structure behind it. Advancements in technology have made easier and better visualisation of internal structures a reality. The following methods aid in such visualisation.

Computed Tomography (CT)

It is also called CAT (Computerised axial tomography) scan. It works on the basic X-ray principle with additional application of new technological systems. When an X-ray beam passes through the body, it is absorbed and scattered by the tissues; the remaining part of the beam that emerges out is attenuated. Every tissue has its own attenuation

profile In the CT picture, the permutations-combinations of various attenuation profiles are computed, analysed and with the aid of computer systems, real images are finally displayed.

Spatial orientation and tissue differentiation are advantages of CT. These are obtained by using the X-ray tube. The person is inside a hole near the tube. The tube rotates and sends X-rays in about 12 beams around the person's entire body circumference. All structures in a single transverse plane are imaged. It is like taking a transverse slice of the body or part of body. Several such transverse sectional images can be taken. It appears as though the body has been cut along the central axis into several sections; that is why the name 'computed axial tomography' (axial=indicating the axis, tome=cutting, graphy=picture). All structures are clearly visualised and it is possible to detect haemorrhages, infarctions and tumours with ease.

Multiplanar reconstruction, spiral or ***helical CT*** and ***high resolution CT*** are advanced methods and techniques of CT.

Ultrasonography

It is a completely different method of imaging. It does not use any part of the electromagnetic spectrum (X-rays are part of the electromagnetic spectrum and both conventional radiography and CT use X-rays). Mechanical oscillations are used. Oscillations between the frequency limits of 20 Hz (Hertz) and 20 kHz (Kilohertz) are heard by human ear as audible sounds Oscillations above 20 kHz are ultrasounds. Ultrasound waves are made to pass through tissues; depending upon the state and condition of the tissues, the waves are reflected. The echo of the sound wave is thus obtained and then computed into an image.

- ***Doppler ultrasonography*** is used for visualising vessels. Assessment of vascular status of various organs and their circulation levels can be studied. In Doppler studies, the echo signals are not from the vessels but from the red blood cells moving through the vessels.

Since ultrasonography involves echo images, it is also called 'echo study'. There is no radiation involved; hence, ultrasound is used in determining the condition of developing foetus. When air-filled structures (e.g., lungs) or structures surrounded by bone (e.g., brain surrounded by cranial box) are involved, ultrasound is of no use because the waves dissipate rapidly in air or cannot penetrate bone

Magnetic Resonance Imaging (MRI)

It involves complex physical phenomena. An image is formed under a magnetic field using radiofrequency impulses. It essentially maps the hydrogen content of the body. Most of the body tissues are in a water medium and MRI differentiates tissues on the basis of differences in water content. For example, grey matter of the brain contains more water than the white matter which is more fatty. Water content in bones is minimal and so bones are not seen at all. Therefore, in as MRI picture, the brain can be well seen without the impediment of the cranium. MRI pictures give clear and minute details, thus enabling rapid diagnosis and effective treatment. However, patients with metallic implants (like pacemakers, tooth fillings) cannot be subjected to MRI. ***Magnetic Resonance Spectroscopy*** maps the distribution of various elements in the body other than hydrogen

- ***Single Photon Emission Computed Tomography*** (SPECT) and ***Positron Emission Tomography*** (PET) are advanced imaging methods. In both these methods, radioactive isotopes are injected into the body through the blood stream. In SPECT, images of gamma radiation emitted by the isotopes are then taken. In PET, such isotopes which emit particles called positrons are used; these positrons in turn lead to production of gamma radiation. Images of gamma radiation are taken. The gamma images are converted into electrical impulses and then a computer reconstructs images of isotope location in the body. Substances like sugar or water can be tagged with radioactive material and the chemical processes taking place within the body can be estimated Sugar uptake in the brain can thus be studied; information about cerebro-vascular accidents and conditions like Alzheimer's disease can be obtained.

Digital Subtraction Angiography (DSA)

It is another computer-based technique. A contrast material is injected into the requisite artery. Images are taken both before and after injection of the material. A computer then subtracts the 'pre' (before) image from the 'post' (after) image. All structures which tend to block 'view' of the vessel are eliminated virtually. The image of the vessel is then studied. Blockage of arteries can be well estimated by this method.

Ranging from X-rays to MRI, all these methods produce images and pictures of images. All these, therefore, are collectively called ***imaging sciences*** and the method of using these sciences for medical diagnosis and treatment is ***medical imaging***.

It can well be understood that a sound knowledge of normal and variant anatomy is essential for proper interpretation of the 'images ; study of anatomy with emphasis on the imaging aspect is 'radiological anatomy'.

Multiple Choice Questions

1. Bones are radio-opaque due to:
   a. High calcium content
   b. Rod-like shape
   c. Presence of medullary cavity
   d. Their cartilaginous base

2. In a posteroanterior X-ray, the X-ray source is:
   a. Posterior to the individual
   b. Posterior to the radiographic plate
   c. Anterior to the individual
   d. Lateral to the individual

3. Angiography is an example of:
   a. Contrast radiography
   b. Fluoroscopy
   c. Ultrasonography
   d. MRI

4. In CT scan, images are like:
   a. Transverse slices along the central axis
   b. Transverse slices along the anteroposterior axis
   c. Sagittal slices along the central axis
   d. Sectional slices along the transverse axis

5. The imaging technique that maps elements in the body other than hydrogen is:
   a. Magnetic resonance imaging
   b. Magnetic resonance spectroscopy
   c. Single photon emission computed tomography
   d. Positron emission tomography

ANSWERS

1. a **2.** a **3** a **4.** a **5.** b

Clinical Problem-solving

Case Study 1: A 48-year-old man had right knee pain for about 6 months. He was asked to have an MRI picture taken of his knee joint. Having heard of X-ray images since his younger days, the man felt a plain X-ray would give a better idea of the interior of his knee.

- What is the advantage that an MRI picture has in an area like the knee?
- Why would not the plain X-ray be sufficient?
- Which chemical element forms the basis of MRI detection?

Case Study 2: A 43-year-old woman had chronic complaints of abdominal pain and vomiting. Her physician advised a barium meal picture.

- Why is a barium meal picture taken?
- Why would an ordinary X-ray be insufficient in this case?
- Name a few other contrast X-rays.

(For solutions see Appendix).

Section 2

Upper Limb

Chapter 10

Overview of Upper Limb

Frequently Asked Questions

- Write notes on (a) Cephalic vein, (b) Median cubital vein, (c) Cutaneous innervation of front of arm.
- Describe the cutaneous innervation of the palm.
- Discuss the superficial lymphatic drainage of the upper limb.

REGIONS OF THE UPPER LIMB

The upper limb is an extension of the upper part of the trunk and is specialised to grasp, strike and produce fine movements, help the individual hold and carry things and perform intricate skills. The term 'manipulation' traces its origin from the Latin word *manipulus*, meaning 'handful'; it originally meant skilful performance of actions, which is a special characteristic of the human hand due to exclusive anatomic features. The bones of the upper limb are attached to the axial skeleton by the pectoral girdle.

For sake of description, the upper limb can be subdivided into various regions. These regions are:

- ***Pectoral region (regio pectoralis):*** It is the part overlying the anterior chest wall. Though this region appears to be part of chest (Latin pectus=chest or breast), the muscles of this region attach the upper limb to the trunk and thus perform a mooring action. Due to this functional relationship, the pectoral region is usually classified as a part of the upper limb.
- ***Scapular region (regio scapulare):*** It is the part overlying the shoulder blade. Similar to the pectoral region, this region also has mooring muscles and hence is a part of the upper limb.
- ***Deltoid region (regio deltoidale):*** It is area of the curve of the shoulder.

The three regions mentioned above are collectively called the ***region of the shoulder***. The area over the lower part of the neck is sometimes included in the shoulder region.

- ***Arm (regio brachium):*** It is the part of the limb between the shoulder and the elbow and is the longest segment of the limb.
- ***Elbow region (regio cubitus):*** It is the region of the elbow joint and is slightly wider than both its proximal and distal continuities, the arm and the forearm.
- ***Forearm (regio antebrachium):*** It is the part of the limb between the elbow and the wrist and is the second longest segment of the limb.
- ***Wrist (regio carpus):*** It is the region of the wrist joint and is the area where increase in mobility is maximally perceived
- ***Hand (regio manus):*** It is the most distal part of the limb and is the most mobile; it is richly supplied with sensory nerve endings for appreciation of touch, pressure and temperature.

Another additional region usually studied along with upper limb is the axilla. The axilla can be defined as an irregularly shaped pyramidal area found between the shoulder and the upper thorax. The apex of the pyramid opens into the neck and the base of the pyramid is the familiar 'armpit'

While summarising on the distribution of the various regions of the upper limb, it can be seen that there are three major 'gateways' guiding passage of vessels and nerves to different regions. These are:

1. ***Gateway to the upper limb***, as a whole, is the axilla; since the apex of the axilla opens to the neck, all major structures passing to the limb from the neck, pass through the axilla; thus, axilla is usually dubbed as the 'gateway to the upper limb'.
2. ***Gateway to the forearm,*** is the cubital fossa; the brachial artery and the median nerve pass through the cubital fossa, making it the gateway.
3. ***Gateway to the palm,*** is the carpal tunnel; the small osseofibrous tunnel, formed in the anterior aspect of

the wrist, serves as a passage for the tendons of the long flexor muscles and the median nerve.

SURFACE LANDMARKS

It is essential to know some of the important landmarks of the limb so that references are properly made and understood.

- ***Sternum:*** Though it is the breast bone and is part of the anterior chest wall, references are often made to it when the structures of the upper limb are being described. It is felt in the midline on the chest wall as a flat bone; its uppermost margin can be felt as a notch in the midline at the junction of the anterior part of neck and the anterior chest wall. This notch is referred to as the ***jugular notch*** or the ***suprasternal notch.***
- ***Clavicle:*** It is a horizontally placed bone that can be felt running laterally from the upper lateral part of the sternum till the tip of the shoulder. This bone is concavo-convex. The medial end of the clavicle (called the sternal end) can be felt as an elevated prominence above and lateral to the jugular notch.
- ***Coracoid process of scapula:*** It is more often called the digital process, can be felt about 1 inch below the lateral end of clavicle. To palpate this process, the deltopectoral groove should be identified and then fingers insinuated into the groove, pushing a little laterally
- ***Scapula:*** Though the scapula is not completely subcutaneous, its inferior angle and medial border can well be felt and also seen in most individuals. The inferior angle also serves a guide to the upper limits of diaphragm and liver (an abdominal organ) and lower limits of lungs (thoracic organs).
- ***Acromion of the scapula:*** It is the bony point that forms the point of the shoulder in thin individuals, the triangular superior aspect of the acromion can not only be felt easily, but also seen.
- ***Bony arch of the shoulder:*** It is a bony arch felt easily when the examining fingers are run from the anterior to the posterior aspect. The full length of clavicle, the acromion of the scapula and the spine of scapula form this arch.
- ***Acromioclavicular joint:*** This is a subcutaneous joint. It can be felt immediately above and medial to the lateral curve of the shoulder. When the examining fingers are pressed medially, the joint can be felt; the acromial end of clavicle projects above the acromion itself.
- ***Rounded curve of shoulder:*** It is formed by the head of humerus and the deltoid muscle.
- ***Epicondyles of humerus:*** These bony prominences can easily be palpated in the elbow region. The medial epicondyle is more prominent and seen well. The lateral epicondyle is palpable easily when the elbow is partially flexed.
- ***Olecranon of the ulna:*** It is a bony prominence felt well on the posterior aspect of the elbow. If the olecranon can be held by the examining fingers and the elbow slowly extended in a living individual, the olecranon can be felt (and seen) to move upward and forward between the condyles of humerus. When the elbow is flexed, the prominences of the medial and lateral epicondyles of humerus and the olecranon of the ulna form an equilateral triangle. When the elbow is fully extended, the three prominences lie in a straight line.
- ***Biceps tendon:*** It can be made out when the elbow is flexed; it stands out as a firm structure in the middle of the front of the elbow.
- ***Posterior border of ulna:*** It is palpable throughout the length of forearm.
- ***Head of ulna:*** It is the rounded prominence seen on the medial side of the dorsal aspect of the wrist, especially when the forearm is pronated.
- ***Head of radius:*** It is the bony point felt in a depression on the posterolateral aspect of the extended elbow; if the forearm is alternately pronated and supinated, the radial head can be felt to rotate.
- ***Radial styloid process:*** It can be palpated on the lateral aspect of the wrist.
- ***Dorsal tubercle of radius:*** It is felt as a small prominence at the middle of the dorsal aspect of the distal end of radius.
- ***Pisiform bone:*** It can be palpated on the anterior side of the medial aspect of the wrist.

Several bony prominences can be palpated in the hand. The heads of metacarpals form the knuckles of the fist. The dorsal surfaces of phalanges are palpable throughout. The knuckles of fingers are formed by the heads of proximal and middle phalanges.

FASCIAE OF UPPER LIMB

The superficial fascia of upper limb is usually thin and contains little fat in certain areas. The deep fascia however, compartmentalises the muscles. The deep fascia in the pectoral region is the ***pectoral fascia***; it invests the pectoralis major muscle. It is continuous inferiorly with the fascia of the anterior abdominal wall and laterally with the axillary fascia. The deep fascia of the axillary floor is the ***axillary fascia***. Deep to the pectoralis major, the deep fascia condenses to form another layer called the ***clavipectoral fascia***. This runs from the clavicle down. It encloses two muscles, namely, subclavius and pectoralis minor and then joins the superior aspect of axillary fascia.

The deep fascia over the lateral aspect of the shoulder forms the ***deltoid fascia*** (fascia over the deltoid muscle). It is continuous anteriorly with the pectoral fascia and posteriorly with the infraspinous fascia. It sends multiple septa into the deltoid muscle.

The muscles surrounding the scapula are also covered by condensations of deep fascia. Most important of these are the supraspinous and the infraspinous fasciae. The ***supraspinous fascia*** overlies and covers the supraspinatus muscle and the ***infraspinous fascia*** overlies and covers the infraspinatus muscle. Both of them are dense.

The deep fascia of the arm forms a circular sleeve around the arm. This is the ***brachial fascia***. The medial and the lateral intermuscular septa start from the internal aspect of the brachial fascia and run to the humerus to get attached to the shaft and the medial and lateral supracondylar ridges respectively. This arrangement subdivides the arm into two compartments—one anterior to the humerus and the two septa and the other posterior. The anterior is the flexor compartment consisting of the flexor muscles. The posterior is the extensor compartment with the extensor muscles. The deep fascia of the forearm is also in the form of a sleeve around the forearm. It is the ***antebrachial fascia***. Due to the presence of the interosseous membrane between the two bones of the forearm, an anterior (flexor) compartment and a posterior (extensor) compartment are established.

The antebrachial fascia thickens to form the ***extensor retinaculum*** over the distal dorsal portion of the forearm. It also forms a similar anterior thickening which is continuous with the extensor retinaculum at the sides; this thickening is called ***the palmar carpal ligament***. Slightly distal and deeper to the palmar carpal ligament, the antebrachial fascia forms the ***flexor retinaculum***; otherwise and clinically called the transverse carpal ligament, this band gets attached to the prominences of the carpal bones and converts the concavity of the wrist into a tunnel (carpal-tunnel). In the palm, the deep fascia forms the ***palmar fascia***; the central part of the palmar fascia thickens to form the ***palmar aponeurosis*** and the ligaments associated with it.

CUTANEOUS INNERVATION OF UPPER LIMB

Cutaneous innervation of the upper limb can be studied under eleven regions, namely; (a) pectoral region, (b) axillary region, (c) deltoid region, (d) front of arm, (e) back of arm, (f) medial aspect of arm, (g) lateral aspect of arm, (h) front of forearm, (i) back of forearm, (j) palm of hand and (k) dorsum of hand (Figs 10.1 and 10.2).

A. Pectoral Region

Above the level of the 2nd rib, the skin of the pectoral region is supplied by the ***supraclavicular nerves***. Below the 2nd rib, the anterior cutaneous nerves and the anterior branches of the lateral cutaneous nerves supply the skin. It appears that the upper part of the pectoral region (i.e., above the 2nd rib) has drawn its skin from the neck, like a rubber sheet being pulled down and hence the innervation by the supraclavicular nerves

Dissection

With the cadaver in the supine position, palpate the following structures:
- Sternum, suprasternal notch, sternal angle;
- Clavicle;
- Coracoid process of scapula, acromion, parts of the bony arch of shoulder palpable from in front and sides;
- Acromioclavicular joint;
- Epicondyles of humerus.

With the cadaver in prone position study the following:
- Scapula, especially the inferior angle and the medial border;
- Bony arch of shoulder;
- Olecranon and posterior border of ulna;
- Head of radius, radial styloid and dorsal tubercle.

As each region of the upper limb is being dissected, see and study the superficial veins, the cutaneous nerves and the fasciae of the region.

Utilise all opportunities to see and study the following:
- Dorsal venous arch.
- Basilic and cephalic veins.
- Radial, median and ulnar nerves and their branches.
- Cutaneous nerves of the upper limb.

B. Axillary Region

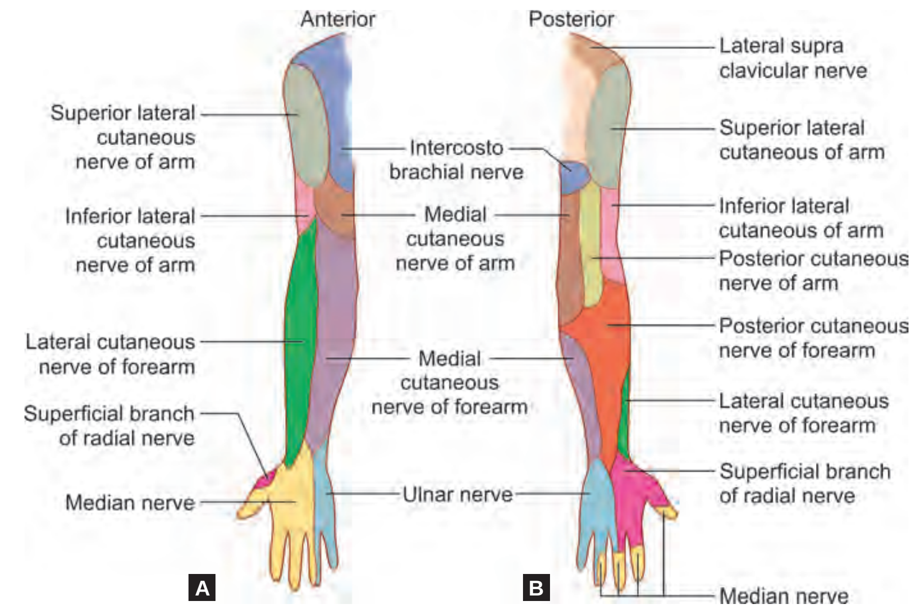
The skin at the base of axilla is supplied by the ***intercostobrachial*** nerve and the T3 spinal nerve.

C. Deltoid Region

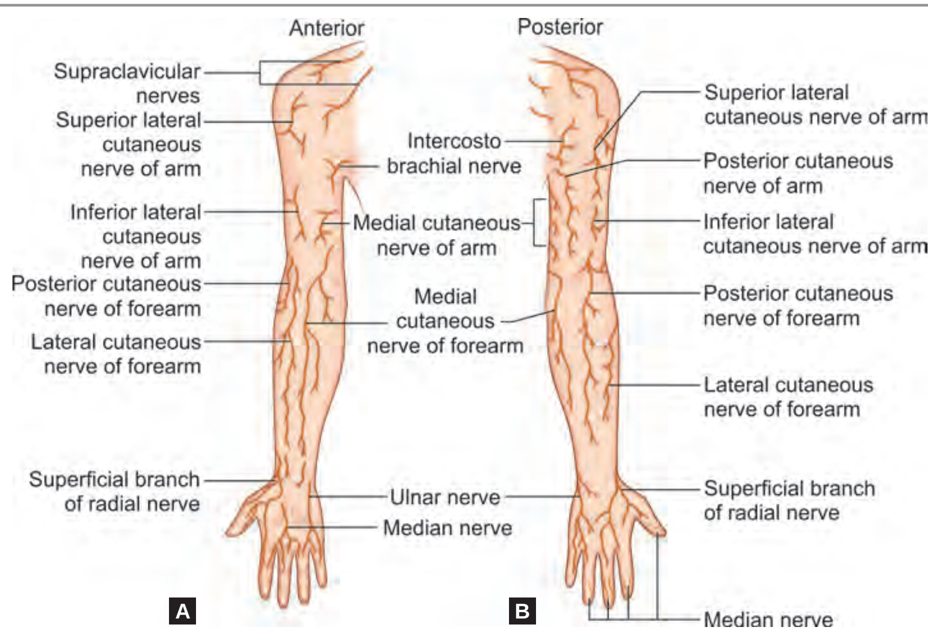
The upper half of the deltoid region is supplied by the ***supraclavicular nerves*** (the extension from the neck thus covers the upper parts of both the pectoral and deltoid regions). The lower part of this region derives its supply from the ***superior lateral cutaneous nerve of arm***, which is a branch of the axillary nerve. A small portion on the posterior aspect of the shoulder curve is supplied by the dorsal ramus of T2 spinal nerve.

D. Front of Arm

Close to the axilla, the medial part of the front of arm is supplied by twigs from the ***intercostobrachial nerve***. From below this, a medially placed broad strip on the front is supplied by the ***medial cutaneous nerve of arm***. At the elbow, a small portion on the medial side is supplied by the ***medial cutaneous nerve of forearm***. The skin of the lateral part of the front of arm (that below the deltoid region) derives its nerve supply from the ***inferior lateral cutaneous nerve of arm*** (a branch of radial nerve). At the elbow, a small portion on the lateral side may be supplied by twigs from the ***posterior cutaneous nerve of forearm*** (also a branch of radial nerve). The area of distribution by the superior lateral cutaneous nerve extends almost till the middle of arm and so, the supply area of inferior lateral cutaneous nerve of arm is reduced to a narrow strip.



Figs 10.1A and B: Simple and schematic representation of the cutaneous innervation of upper limb



Figs 10.2A and B: Schematic representation showing the cutaneous nerves of upper limb

E. Back of Arm

Cutaneous innervation of back of arm can well be described to be in three vertical strips. From medial to lateral, these strips are supplied by the ***medial cutaneous nerve of arm***, ***posterior cutaneous nerve of arm*** and the ***inferior lateral cutaneous nerve of arm***. Close to the elbow, the lateral strip is supplied by twigs from the posterior cutaneous nerve of forearm which may overlap considerably into the territories of the posterior cutaneous and inferior lateral cutaneous nerves of arm.

F. Medial Aspect of Arm

Innervation from the medial side of the anterior and posterior surfaces of arm extend to the medial aspect. The intercostobrachial nerve, medial cutaneous nerve of arm and the medial cutaneous nerve of forearm supply from above downwards

G. Lateral Aspect of Arm

Innervation from the lateral side of the anterior and posterior surfaces of arm extend to the lateral aspect. The lateral supraclavicular nerve, the superior and inferior lateral cutaneous never of arm supply from above downwards. Close to the elbow, the lateral cutaneous nerve of forearm may overlap.

H. Front of Forearm (Fig. 10.3)

Front of the ulnar side (medial side) of the forearm till the level of wrist is supplied by the branches of ***medial cutaneous nerve of forearm***. The lateral side derives innervation from the branches of ***lateral cutaneous nerve of forearm***. A very small portion on the lateral side, close to the elbow, may be supplied by the posterior cutaneous nerve of forearm or the inferior lateral cutaneous nerve of arm.

I. Back of Forearm (Fig. 10.4)

Cutaneous innervation of the back of forearm can conveniently described to be in two halves: back of ulnar side supplied by posterior branches of ***medial cutaneous nerve of forearm***; back of radial side supplied by branches

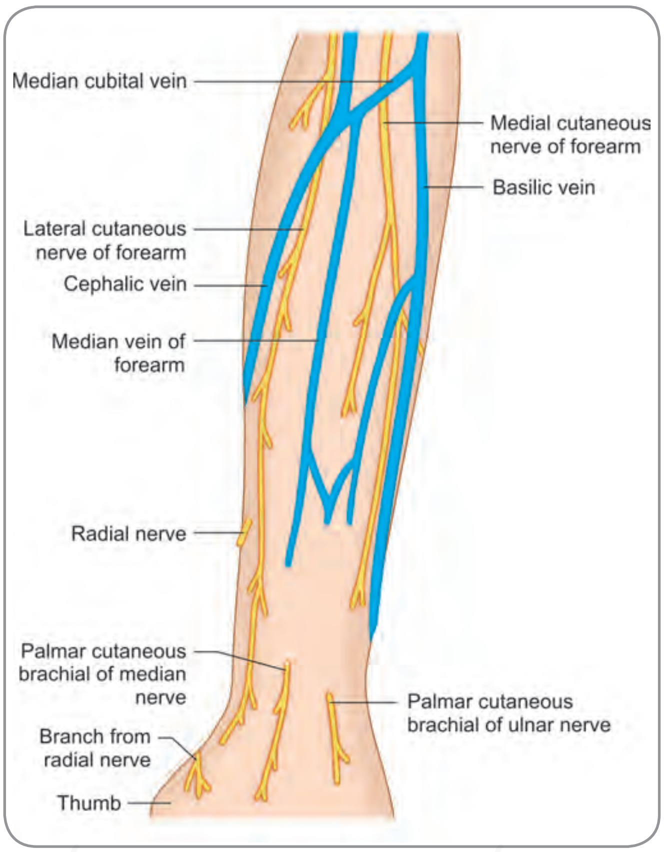


Fig. 10.3: Front of forearm and wrist-superficial nerves and veins

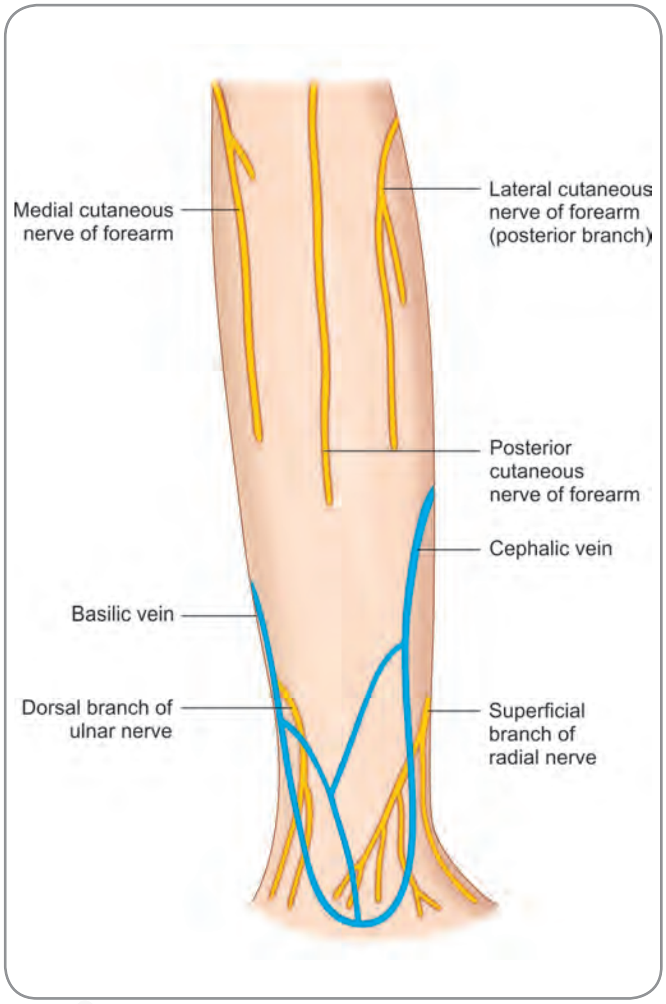


Fig. 10.4: Back of forearm-superficial nerves and veins

of the ***posterior cutaneous nerve of forearm***. A thin narrow strip over the lateral border of the distal third of forearm is supplied by the posterior branch of the lateral cutaneous nerve of forearm.

J. Palm of Hand (Fig. 10.5)

The musculocutaneous nerve, the radial nerve, the median nerve and the ulnar nerve give a palmar cutaneous branch each and these are involved in the innervation of the palm. The ***palmar cutaneous branch of the musculocutaneous nerve*** is given out as a branch of the lateral cutaneous nerve of forearm (which is the cutaneous branch of musculocutaneous nerve) and supplies the ball of thumb. The ***palmar cutaneous branch of the radial nerve*** is given out as a twig from the superficial branch of the radial nerve and also ends in the ball of thumb. The remaining part of the palm, from a little proximal to the wrist, is supplied by the ***palmar cutaneous branches of the median and the***

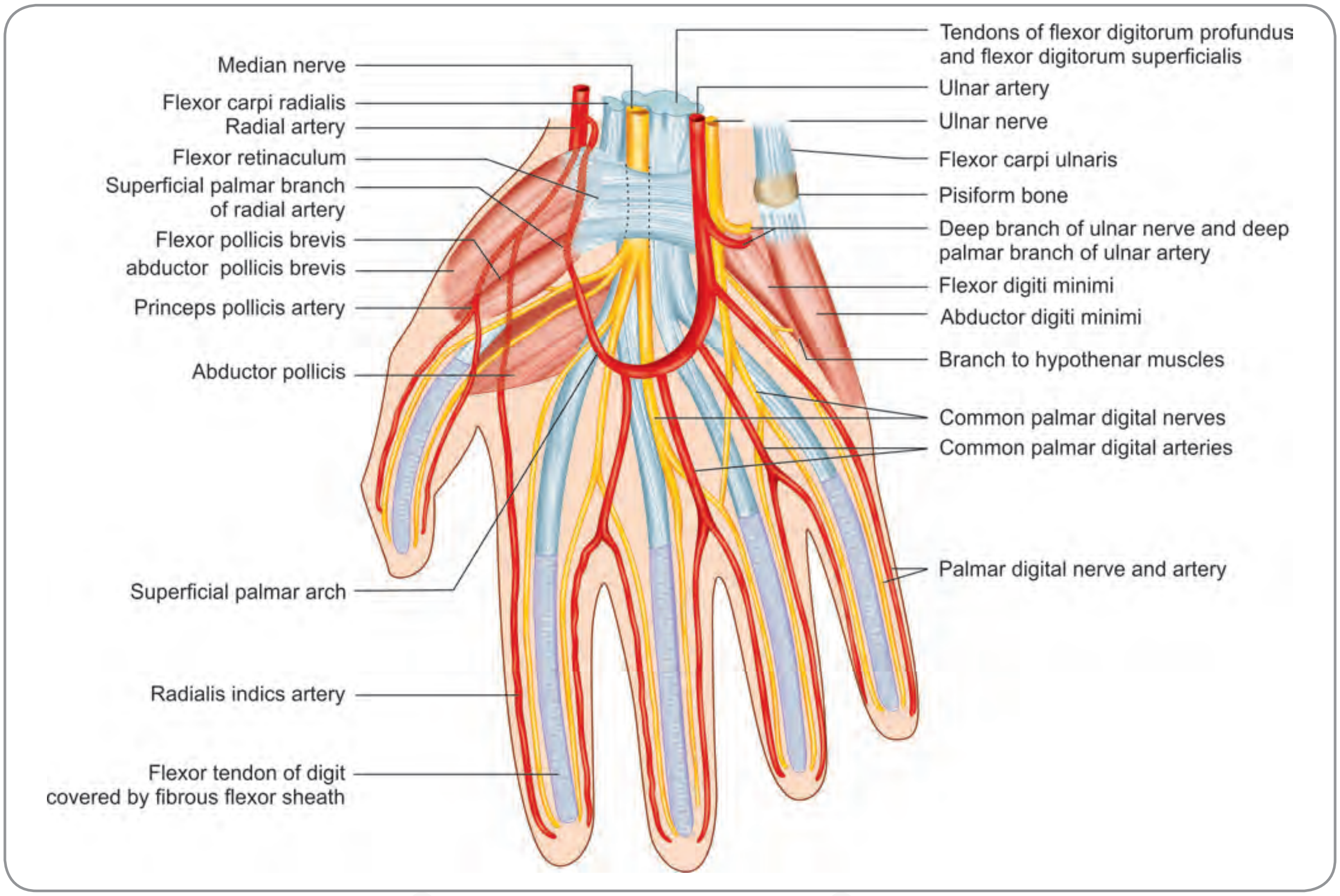


Fig 10.5: Scheme to show the arteries and nerves of the palm

ulnar nerves, with the median taking a larger lateral share and the ulnar taking a smaller medial share.

The palmar aspects of the fingers have a characteristic cutaneous innervation. The common palmar digital branches of the median and ulnar nerves are the sources of supply. Five common palmar digital branches are given out of the median nerve in the hand. Similarly, two (medial and lateral) common palmar digital branches are given out of the ulnar nerve in the hand. Three of the five branches of the median nerve are separate branches to the two sides of the thumb and the lateral side of the index finger. The remaining two divide into two each at the interdigital clefts of the second and third and the third and fourth fingers. These are the proper palmar digital branches which supply the adjacent sides of the 2nd and 3rd and the 3rd and 4th fingers. Of the two branches of the ulnar nerve, the medial branch supplies the medial aspect of the little finger. The lateral branch divides into two proper palmar digital branches to the adjacent sides of the ring and the little fingers. Thus, the median nerve supplies the lateral 3½ fingers and the Ulnar nerve supplies the medial 1½ fingers.

The palmar digital nerves to a particular finger supply the skin and fascia on the entire palmar surface of the concerned finger and the skin and fascia on the dorsal aspect of the middle and distal phalanges (including the nail bed). In the thumb, the skin and fascia on the back of only the distal phalanx are supplied by the palmar digital nerves.

K. Dorsum of Hand (Fig. 10.6)

The lateral aspect of the dorsum (including the dorsal aspects over the proximal phalanges of the concerned fingers) is supplied by branches of the radial nerve and the medial aspect by those of the ulnar nerve, retaining the 3½–1½ pattern of distribution. The dorsal aspects over the middle and distal phalanges, as already noted, have a median (lateral 3½) and an ulnar (medial 1½) distribution.

Dermatomal Map of the Upper Limb

Dermatome is the area of skin that is supplied by one ventral ramus (the ventral ramus of one spinal nerve) through its various cutaneous branches.

It is imperative to learn some facts about the ***development of the limbs*** before attempting to know about the dermatomes of the upper limb.

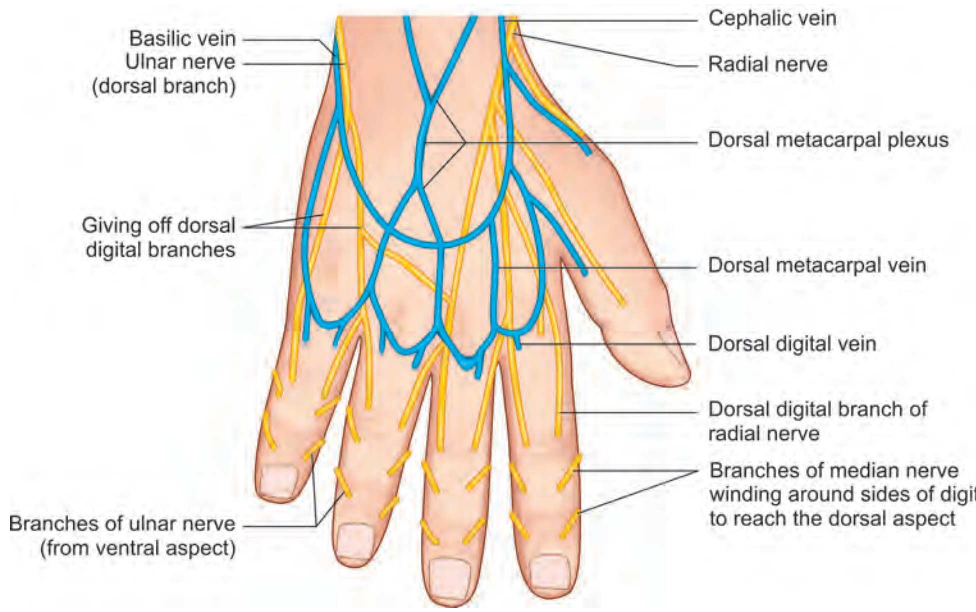


Fig. 10.6: Dorsum of hand-superficial nerves and veins

- The limb buds appear as lateral outpouchings of the trunk of a developing embryo. During the sixth week of intrauterine life, localised proliferations (two pairs) of mesoderm lining the body wall occur; the cranial pair is at the level of lower six cervical and upper two thoracic spinal segments. This pair develops into the pair of arm buds which project from the trunk of the embryo as two lateral projections.
- These projections soon become flattened ventrodorsally, thus developing a cranial border, a caudal border, a ventral surface and a dorsal surface. Since the central axis of the limb passes through its middle, the cranial border is called the preaxial border and the caudal, the postaxial border.
- As the limb buds elongate further, the ventral (anterior) rami of the spinal nerves situated opposite, start growing into them. Mesenchyme (future muscle) along the preaxial border receives innervation from the lower cervical nerves and that along the postaxial border receives twigs from the eighth cervical and upper two thoracic nerves.
- Little later, the mesenchymal masses divide into anterior and posterior groups of muscles and so, the nerves also divide into anterior and posterior divisions. At the next stage, the various muscles migrate to their adult positions within the developing limb and draw their nerve supply along. Consequently, the nerves undergo twisting, turning and realigning, leading to the formation of a plexus of the ventral rami. The ventral (anterior primary) rami of the lower cervical and upper thoracic spinal nerves thus form the Brachial plexus.
- Parallel to these developments, the upper limb buds also rotate laterally, thus making the cranially placed thumb (preaxial) to become lateral and the caudally placed little finger (postaxial) to become medial.

The dermatomes of the upper limb follow the basic pattern of segmental innervations with modifications brought about by muscular migration and limb rotation. The lateral aspect is supplied by more cranial spinal segments than the medial aspect. The nerves to the free upper limb (that part of the limb which is not attached or anchored—from the upper arm to the finger tips) are from the brachial plexus; the shoulder region is mostly supplied by the cervical plexus.

The cervical dermatomes C3 and C4 (cervical plexus) are one below the other in the base of neck and extend laterally to the shoulder C5 occupies the lateral half of front of arm and extends to the lateral half of the upper third of forearm. C6 dermatome occupies the position below C5 and innervates the lateral aspect of front of forearm, thenar aspect of palm, palmar aspects of thumb and lateral half of forefinger. C8 occupies the medial aspect of front of forearm, the hypothenar area and the palmar aspects of medial half of ring and whole of little fingers. Between the C6 and C8, C7 occupies a thin strip over the middle area of front of forearm expanding into a triangle over the palm and continues on the medial half of fore, whole of middle and lateral half of ring fingers. T1 and T2 occupy medial aspects of forearm and arm one above the other, with T2 extending to the pectoral region below the C3, C4 innervations of the shoulder.

On the dorsal aspect, the threefold distribution of C6, C7 and C8 continue upwards from the fingers. The dorsal aspect of thumb and lateral half of forefinger, the radial border of hand and forearm (till the middle third) and a narrow strip on the back of the limb till the shoulder are subserved by C6. C7 occupies the medial half of fore, whole of middle and lateral half of ring fingers and continues upward as a tapering strip over the back of hand and forearm. C8 occupies the medial half of ring finger and the whole of little finger and continues upward till the middle third of forearm. T1 ascends up from the proximal third of forearm to middle of arm. T2 ascends from back of arm to the shoulder.

Added Information

- Though the muscles of the upper limb derive their nerve supply from spinal segments C5, C6, C7, C8 and T1 through the brachial plexus, the cutaneous supply is much more extensive. Four additional spinal segments are usually involved, two cranial (C3 and C4) and two caudal (T2 and T3).
- Variations in the pattern of cutaneous distribution in the palm and dorsum of hand are many and commonly occur. On the palmar aspect, the ulnar nerve may take over supply till the middle finger; on the contrary, the median nerve may supply till the ring finger. On the dorsal aspect, the territories of ulnar and radial nerves may increase or decrease. The posterior cutaneous nerve of forearm may extend its territory to the dorsum.
- Delineating dermatomes as separate zones is only for sake of description and convenience. In reality, there is much overlap.
- Variations in the distribution of the peripheral areas of dermatomes are also frequently noted and can be seen from side to side in the same individual.
- The dermatomal map described above is the one proposed by Foerster in 1933. This map is clinically correlated, especially with the pain of heart attacks referred to the upper limb Another map proposed by Keegan and Garrett in 1948 is more popular, especially among anatomists, due to its aesthetically suited geometric appearance and better correlation with developmental factors.

VEINS OF UPPER LIMB

The venous drainage of the upper limbs is carried out by two separate sets of veins namely, the superficial and the deep sets (Fig. 10.7).

1. Most of the blood is returned through ***superficial veins*** which lie in the superficial fascia and have no relationship to the arteries of the limb.
2. The ***deep veins*** run along the arteries and are situated deep to the deep fascia.

Superficial Veins

The superficial veins of the upper limb begin from the hand and run on either side of the forearm. They enter

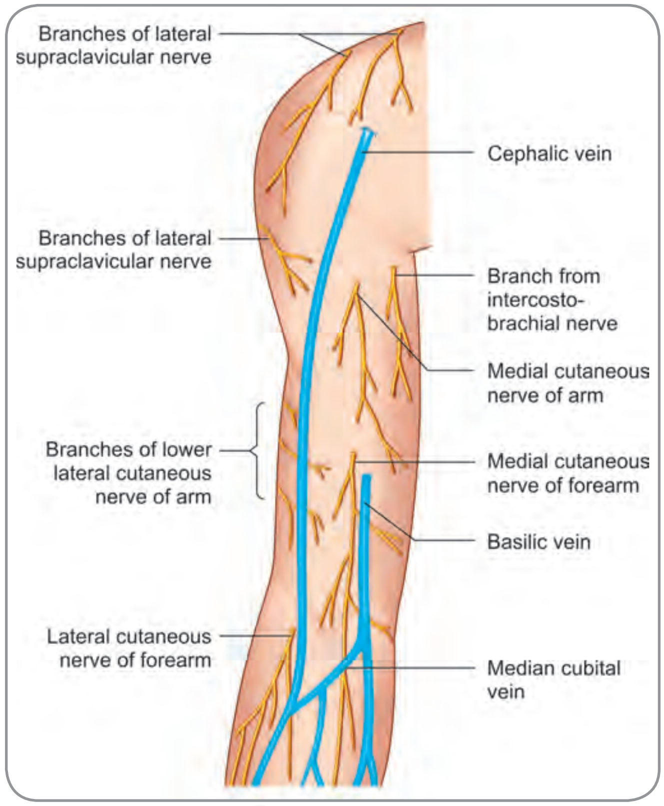


Fig. 10.7: Cutaneous nerves and veins in the front of arm

the deep fascia ultimately and join the deep veins either in the arm or the pectoral region. Their course and levels where penetrations of deep fascia occur are subject to considerable variations. The most common patterns are explained below.

Each finger is drained by two sets of digital veins, the dorsal and the ventral. The ***dorsal digital veins*** from the adjoining sides of the medial four digits end by forming three ***dorsal metacarpal veins*** which in turn join each other to form a ***dorsal venous network*** over the dorsum of the hand. The network is also joined by digital veins from the thumb, the radial side of the index finger and from the ulnar side of the little finger. The palmar digital veins drain into a superficial plexus in the palm and partly communicate with dorsal digital veins through intercapitular veins passing between the metacarpal heads. The veins of the hand are further drained by two main superficial veins These are the ***cephalic*** and ***basilic*** veins.

The ***cephalic vein*** (Greek.kephalos=head) begins from the lateral side of the venous network on the dorsum of hand at the anatomical snuff box. It ascends along the radial border of the wrist; though it is on the posterior aspect in the lower part of the forearm, it winds around the radial border to reach the anterior aspect. It traverses in front of the lateral part of the elbow and runs upwards in the arm along the lateral side. In the upper part of the arm, it comes to lie in the groove between the anterior

margin of the deltoid muscle and the pectoralis major (the deltopectoral groove). It then pierces the clavipectoral fascia and ends in the axillary vein The cephalic vein receives several tributaries along its course. The largest of these is the ***accessory cephalic vein*** which joins it near the elbow. The cephalic vein, which is often visible through the skin almost throughout its course, is connected to the basilic vein by the ***median cubital vein.***

The ***basilic vein*** begins from the medial side of the venous network on the dorsum of hand. It ascends along the ulnar side of the forearm, first on the posterior aspect and then winding around the ulnar border to reach the anterior aspect. It traverses along the medial side of elbow, runs upwards and at the middle of the arm it pierces the deep fascia where it lies medial to the brachial artery. At the level of the lower border of Teres major, it is joined by the venae comitantes of brachial artery to form the axillary vein. Most of the basilic vein is visible through the skin in thin individuals.

The ***median cubital vein*** lies in front of the elbow joint in the cubital fossa. It passes upwards and medially from the cephalic vein to the basilic vein. It is often the largest vein in the region and is frequently used for taking blood samples or for giving intravenous injections and blood transfusions.

The ***palmar venous plexus*** is drained by the ***median vein of the forearm*** (also called the ***median antebrachial vein***). This vein usually begins at the base of the thumb either on the ventral or the dorsal aspect, ascends in the middle of front of forearm and ends in the basilic vein or the median cubital vein in or near the cubital fossa. It sometimes divides into a median basilic vein and a median cephalic vein which join the basilic and cephalic veins respectively, giving rise to an M-like pattern.

Deep Veins

The deep veins accompany the arteries of the limb. They are small in calibre and are often paired and may form plexuses around the arteries they accompany. Such veins are called ***venae comitantes***. They are found in relation to the palmar digital and palmar metacarpal arteries, the dorsal metacarpal arteries, the superficial and deep palmar arches, the radial and ulnar arteries, the anterior and posterior interosseous arteries and the brachial artery. The veins accompanying the brachial artery join (near the lower border of the Teres major) with the basilic vein to form the axillary vein

Added Information

After serious injuries and in some diseases, a patient may go into a state of shock. Blood pressure falls and the superficial veins may not be visible. In such cases, it is useful to remember that the cephalic vein lies just behind the styloid process of the radius.

Clinical Correlation

- Knowledge of the anatomy of the superficial veins of the upper limb is important as they are commonly used for withdrawal of blood, intravenous infusions and more sophisticated procedures like cardiac catheterization. The median cubital vein is frequently used but any other easily located vein may also be used.
- Anastomosis between the radial artery and the cephalic vein is done creating an arteriovenous fistula for the purpose of haemodialysis, in patients with renal failure.
- A vein canulated for infusion may develop ***thrombosis*** (clot formation).
- Thrombosis accompanied by inflammation is called ***thrombophlebitis***. In this condition the vein concerned is inflamed and present as a painful cord-like structure.
- A vein can be damaged by direct injury or even by unaccustomed movement. For example, working for long periods with an arm raised can result in thrombosis in the axillary vein.
- In the developing embryo, the cephalic vein is found to cross over the clavicle and end in the external jugular vein. Necessary changes may not occur and the vein may continue to do so in some adults too.

LYMPH NODES AND THE LYMPHATIC DRAINAGE OF UPPER LIMB

The lymph nodes of the upper limb can be described in two groups, namely, the superficial and the deep groups (Fig. 10.8).

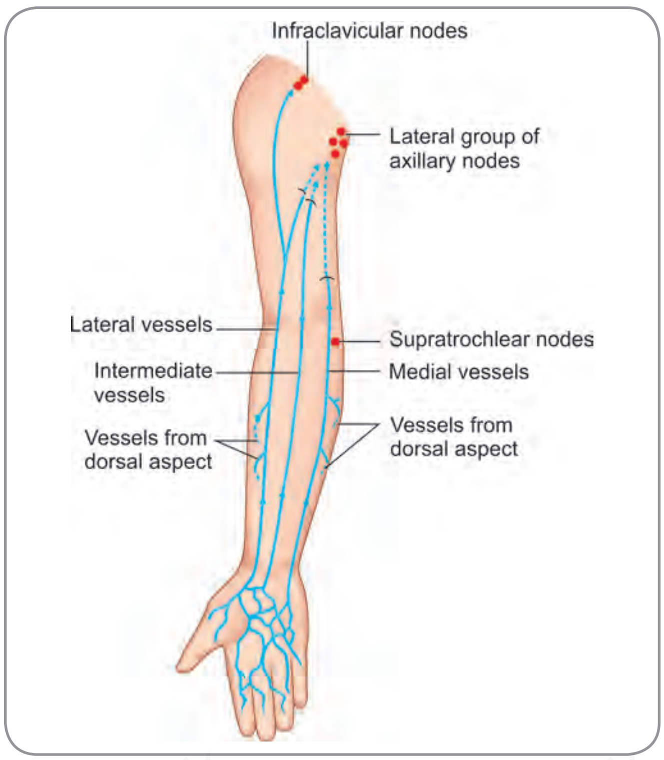


Fig. 10.8: Scheme to show the lymphatic drainage of the upper limb

The ***superficial group*** consists mostly of nodes lying in the superficial fascia. These are the cubital nodes, the infraclavicular nodes and the deltopectoral node. The ***cubital lymph nodes*** (sometimes called the supratrochlear nodes) are found medial to the basilic vein in the region of the cubital fossa. They receive lymphatics from the medial 2½ fingers, medial part of palm and the medial part of forearm. Their efferents travel along the basilic vein to reach deep lymphatics. The ***infraclavicular node*** (rarely two or more) lies in the infraclavicular fossa region close to the cephalic vein. It receives lymphatics from the skin of the shoulder, the skin of the lateral part of upper arm and from the upper part of mammary gland. Its efferents pierce the clavipectoral fascia to drain into the (apical) axillary nodes. The ***deltopectoral node*** is again, usually solitary. It is found in the deltopectoral groove and receives afferents from the skin of shoulder and lateral part of upper arm. Its efferents drain into the infraclavicular node(s).

One set of nodes, which cannot strictly be called 'superficial' (because they are deep to the muscular plane) is the ***interpectoral lymph nodes***. These are a few nodes found between the pectoral muscles. They are actually interspersed in the path of the lymphatics from the mammary gland to the infraclavicular nodes.

The **deep group** consists of the ever important axillary nodes and the 'not-so-important' deep arterial nodes and the deep cubital nodes. ***Deep arterial nodes*** are small-sized nodes present along the radial, ulnar and interosseous arteries. ***Deep cubital nodes*** are the nodes present at the bifurcation of the brachial artery. Lymph nodes along the brachial artery are very rare. Since the deep arterial and deep cubital nodes lie along the path of deep lymphatics of the limb, they receive afferents from several of them. The efferents of all these nodes drain into the (lateral) axillary lymph nodes.

The ***axillary lymph nodes*** deserve special mention (though they are dealt with in the chapter on axilla, a few details are discussed here for better comprehension). They are numerous and are found in the axillary fat. Five groups have been described, namely, the lateral, the anterior, the posterior, the central and the apical groups. The lateral nodes are along the axillary vein, the anterior nodes along the lateral thoracic artery and the posterior nodes along the subscapular artery. The central group of nodes lie scattered in the central part of the axillary fat. The apical nodes are found deep and in continuity with the lateral group. The axillary nodes except the apical group receive afferents from the cutaneous and deep lymphatics of the entire upper limb, the cutaneous lymphatics of the trunk above the umbilical plane and the lymphatics of the mammary gland. The efferents from them pass to the apical group. The apical group apart from receiving lymph vessels from the other axillary nodes, also receives vessels

Development

Synopsis of upper limb development

The upper limb bud is visible as an outpocket from the ventrolateral body wall, on the sides of the pericardial bulge, by the fourth week of intrauterine life. The bud has a mesenchymal core covered by a layer of cuboidal ectoderm. This mesenchyme is derived from the somatopleuric layer of the lateral plate mesoderm. Ectoderm at the distal border of the bud thickens almost immediately to form the Apical Ectodermal Ridge (AER). Due to the influence exerted by the ridge, the mesenchyme proliferates rapidly but remains as a large population of undifferentiated cells close to the ridge. Farther away from the ridge, i.e. in the proximal portion, mesenchyme diffe entiates into cartilage and muscle. The forerunner of the limb is now formed and starts growing proximodistal y.

By the sixth week, the distal most portion flattens to form the hand plate; it is separated from the proximal portion by a circular constriction. The proximal segment soon gets div ded into two halves by another constriction. The main parts of the limb bud, namely, the arm, forearm and hand, can be recognised by the eighth week. Cells in some parts of the apical ectodermal ridge die out; the ridge is thus divided into five parts and these will form the fingers. The five segments of the ridge influence their respective portions; condensation of mesenchyme, under this influence causes cartilaginous phalanges, rudimentary tendons and vascular cords. Further cell death proceeds to establish interdigital space and separation. In the segments which will later develop into arm and forearm, muscles develop. The extensor muscles are dorsal and flexors ventral to the cartilaginous rods.

In the early seventh week, limb bud rotation occurs. The upper limb rotates 90 degrees laterally. It should be noted that before rotation, the limb bud has preaxial and post-axial borders. From the time the limb bud appeared as an out pouch, it has a central axis. However, due to flattening of the hand plate and semi flattening of the forearm segment, preaxial and postaxial borders come to be established. The preaxial border is cranial and postaxial border is caudal. With the lateral rotation of the upper limb bud, the preaxial border becomes lateral and the postaxial medial. The thumb (preaxial) comes to occupy the lateral aspect and the little finger (postaxial), the medial aspect. The extensor muscles become posterior and lateral; the flexors anterior and ventral (correlate with the flexor origin on the medial epicondyle and the extensor origin on the lateral epicondyle of the humerus).

At the end of the sixth week, chondrocytes from the mesenchyme develop cartiginous rods. In places of future joints, chondrogenesis is arrested and interzones (between cartilaginous segments) are formed. The rods become bones; the interzones become joints. Ossification in the cartilaginous rods begins by eighth week. By the 12th week, primary ossification centres are present in all long bones. The upper limb bud is opposite the lower five and upper two thoracic segments. The ventral primary rami from the corresponding segments enter the mesenchyme soon after the bud makes its appearance. Each ventral ramus to start with has a ventral and a dorsal division. Soon, all the ventral divisions unite and similarly the dorsal divisions unite too. The nerves establish contact with the muscular mesenchyme immediately. The radial nerve that supplies the extensor musculature is derived from the dorsal divisions and the median and ulnar nerves from the ventral divisions.

from the infraclavicular nodes. The efferents from the apical nodes go to subclavian lymphatic trunk.

Overall Lymphatic Drainage of the Upper Limb (Except the Mammary Gland)

Superficial lymphatics: The palm and the palmar surfaces of fingers have an intricate plexus of lymphatics. From the palmar plexus of each finger, the efferents run to the dorsal aspect forming the dorsal digital lymph vessels which continue proximally on the dorsum of the hand. From the palm itself, efferents run in all four directions, namely, upwards, downwards, medially and laterally. Those running medially join with the lymphatics of the little finger; those running laterally join with the lymphatics of the thumb. The lymphatics which run downwards, turn dorsally in the interdigital clefts and reach the dorsum. The lymphatics which run upwards proceed proximally. From the meshwork of lymphatics thus formed, a few larger vessels arise and run up. The vessels running on the front of the limb proceed upwards but with an inclination towards the axilla. The vessels on the dorsal aspect wind around the margins and reach the anterior aspect. Some vessels which pass through the region of the cubital nodes are interrupted there. Some vessels which are close to the basilic vein, pass deep to the deep fascia along with the vein, to join the deep lymphatics. The lymphatic vessels of the upper arm also slope towards the axilla and those from the shoulder descend to it. On the posterior aspect of the arm is a linear strip from where the lymphatics part directions. Those medial to the strip wind around the medial margin of the arm and reach the anterior aspect; those lateral wind around the lateral margin and reach the anterior aspect. The linear strip area is called the 'lymph shed'.

It can be seen that all the superficial lymphatics from the upper limb pass to the axillary nodes. A few cutaneous lymphatics close to the upper part of the cephalic vein may pass to the infraclavicular or the deltopectoral nodes, from wherein the efferents reach the axillary nodes (infraclavicular to axillary or deltopectoral to infraclavicular to axillary).

Deep lymphatics: The deep lymphatic vessels, whether interrupted by some closer deep nodes or not, all pass to the lateral axillary nodes. They drain lymph from muscles, joint capsules, periosteum, tendons and nerves.

From the lateral, anterior, posterior and central axillary nodes, efferents pass to the apical nodes and from there reach the subclavian lymph trunk.

MOTOR ACTIVITIES OF UPPER LIMB

The greatest strength of the upper limb is its mobility. Specialised abilities like grip, grasp and strike are well marked in the hand and extremely refined and intricate movements have made much out of humankind.

Synchronisation between the various muscles and joints is essential for smooth and efficient movements to occur. Movements at the shoulder, elbow, wrist and smaller joints interplay to produce the best workable distance for the entire upper limb and the best position for the hand to undertake a suitable task.

Motor supply to the various upper limb muscles is by the same spinal nerves which also convey sensory fibres.

Myotomal Map of the Upper Limb (Table 10.1)

The muscle mass that receives innervation from a single spinal cord segment or spinal nerve is called a myotome It is noted that embryologically unified muscle masses, separate into more muscle segments during development and therefore, in adult life, appear to be separate groups. Also, some muscles derive innervations from more than one spinal segment or nerve indicating a multiple origin.

Most of the upper limb muscles receive fibres from many spinal segments. Similarly many movements of the upper limb have innervation from two or more spinal segments. However, the extremely intricate muscles of the hand receive nerve supply from a single segment; this arrangement gives an advantage of easy coordination.

Table 10.1: Myotomal map of upper limb

Joints	Movements	Spinal segments involved
Shoulder	Flexion	C5
	Extension	C6, C7, C8
	Medial rotation	C6, C7, C8
	Lateral rotation	C5
	Adduction	C6, C7, C8
	Abduction	C5
Elbow	Flexion	C5, C6
	Extension	C6, C7
Wrist	Flexion	C6, C7
	Extension	C6, C7
Radioulnar joints	Supination	C6
	Pronation	C7, C8
MP & IP joints	Flexion of fingers	C7, C8
	Extension of fingers	C7, C8
	Adduction of fingers	T1
	Abduction of fingers	T1

Abbreviation: MP, Metacarpophalangeal; IP, Interphalangeal

Multiple Choice Questions

1. Gateway to the palm is formed by the:
   a. Axilla
   b. Carpal tunnel
   c. Cubital fossa
   d. Armpit
2. The humeral epicondyles and ulnar olecranon form --------- when the elbow is flexed (Fill the blank by choosing one option):
   a. Isosceles triangle
   b. Straight line
   c. Irregular quadrangle
   d. Equilateral triangle
3. The superior pectoral region is supplied by supraclavicular nerves because it has
   a. Drawn its skin from the neck
   b. Clavicle lying horizontally
   c. The pectoralis major attached to clavicle
   d. The claviculopectoral groove
4 The middle vertical strip of skin on the back of arm is supplied by:
   a. Posterior cutaneous nerve of arm
   b. Posterior cutaneous nerve of forearm
   c. Lateral cutaneous nerve of arm
   d. Intercostobrachial nerve
5. The paired veins which accompany the arteries are called:
   a. Venous plexuses
   b. Venae comitantes
   c. Deep veins
   d. Venous anastomoses

ANSWERS

1. b **2.** d **3.** a **4.** d **5.** b

Clinical Problem-solving

Case Study 1: When you go around the clinical wards, you find some patients being given intravenous drugs. You also find the health care professional trying to locate some veins in the forearm and elbow region for giving such drugs.

- Which vein is commonly sought and used?
- Why is it commonly sought and preferred?
- What other vessels can be used if necessary?

Case Study 2: A 23-year-old youth has an injury in his forearm which is also infected. The entire forearm appears reddish and swollen.

- Which are the lymph nodes you expect to be swollen in this case?
- Why are the axillary lymph nodes invariably involved?
- If the lateral axillary lymph nodes are specifically involved, what would you think?

(For solutions see Appendix).

Chapter 11

Bones of Upper Limb

Frequently Asked Questions

- Write notes on (a) Upper end of Humerus, (b) Olecranon of ulna, (c) Radial tuberosity, and (d) Surgical neck of humerus
- Describe the owe end of humerus.
- Describe the ulna.
- Write notes on: (a) Scaphoid, (b) Hamate, (c) Capitate, (d) Lunate, (e) Lower end of radius, and (f) Uppe end of ulna.
- Discuss the features of clavicle. Add a note on its applied importance.
- Discuss the following: (a) Spine of scapula, (b) Acromion, (c) Glenoid cavity, and (d) Coracoacromial arch.

The evolution of human kind with consecutive adoption of upright posture and bipedal mode of locomotion has resulted in changes not only in the bones of lower limb, but also in the bones of upper limb. The upper limb is made free from locomotion and weight-bearing. Further, the presence of clavicle as a strut facilitates free movement of the upper limb.

The other significant change in human beings is the progressive separation of the thumb from the other fingers enabling the hand to be used for prehension and other skilled movements. To enable these movements, the forearm is endowed with good range of supination and pronation, the shoulder joint is freely mobile and is further facilitated by the mobility at the pectoral girdle.

The upper limb is connected to the trunk by the ***pectoral girdle*** (also called the ***shoulder girdle***) which is composed of scapula and clavicle on each side. These two bones support the shoulder region. Scapula is connected to the trunk only by muscles; clavicle acts as a prop for scapula (Fig. 11.1).

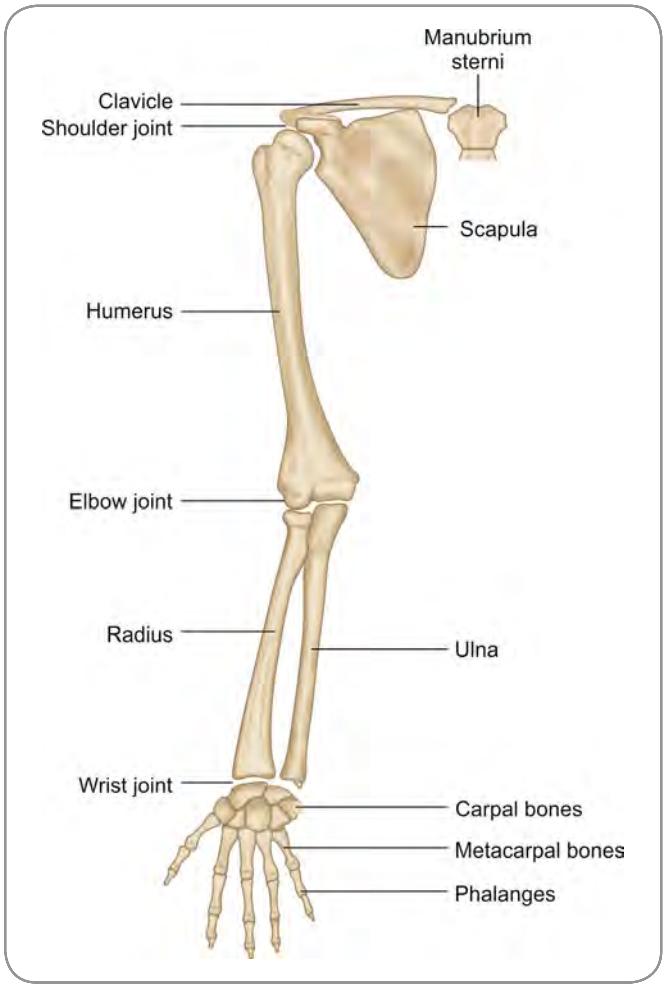


Fig. 11.1: Drawing showing bones and joints of upper extremity

CLAVICLE

Another name: Collar bone

The ***clavicle*** (Latin clavicula=a small key) is a long bone that connects the upper limb to the trunk. It has a shaft and two ends It is situated at the anterosuperior aspect of

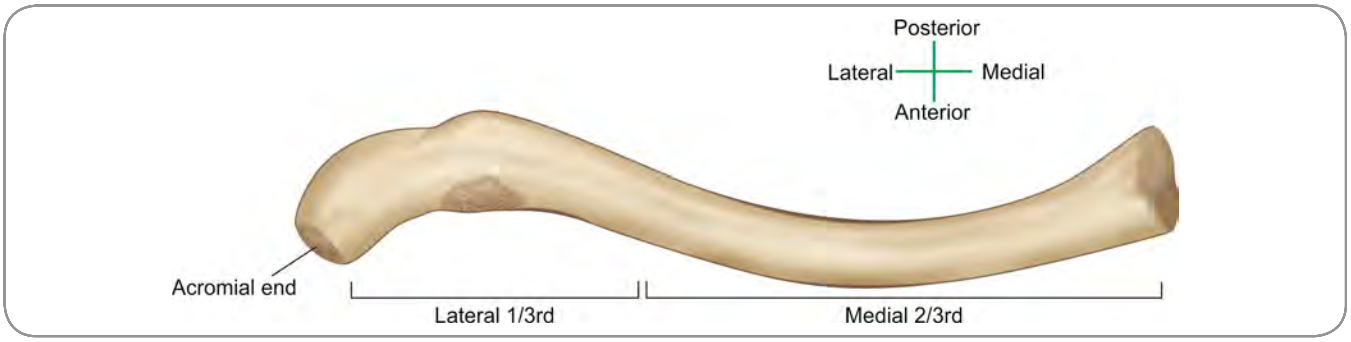


Fig. 11.2: Right clavicle seen from above

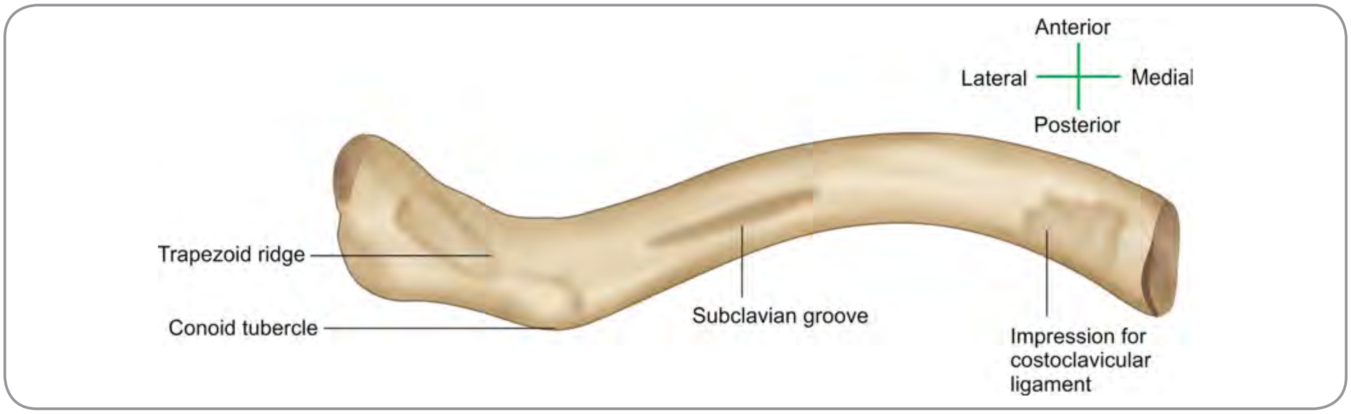


Fig. 11.3: Right clavicle seen from below

the thorax, and articulates with the sternum and the first rib medially and the scapula laterally. The medial end of the bone which articulates with the sternum is called the ***sternal end*** and the lateral end which articulates with the acromion of the scapula is called the ***acromial end***. The bone is readily palpable from end to end; the skin moves over it freely. Its medial part is convex forwards and lateral part concave forwards. The most important feature of clavicle is that in the normal anatomical position, the bone is placed almost horizontally. Lying so, it serves to prevent the shoulder from falling forwards.

Side Determination

- The medial end is much thicker than the shaft and is easily distinguished from the lateral end that is flattened.
- The medial part is convex forwards and the lateral part concave forwards.
- The inferior aspect has a shallow groove on the shaft and a rough area near its medial end.

With the aforementioned information, the side of the given clavicle can be determined.

For purposes of description, it is convenient to divide the clavicle into the lateral one-third which is flattened and the medial two-thirds which is cylindrical. The forward convexity of the medial part is in conformity with the superior thoracic aperture and the forward concavity of the lateral part with the shape of the shoulder.

The ***lateral one-third*** is flattened from above downwards and has two surfaces, i.e., superior and inferior. These surfaces are separated by two borders: ***anterior*** and ***posterior***. The anterior border is concave and shows a small thickened area called the ***deltoid tubercle*** (Fig. 11.2). The inferior surface (of the lateral one-third) shows a prominen thickening near the posterior border called the ***conoid tubercle*** (Fig. 11.3). Lateral to the tubercle is a rough ridge that runs obliquely upto the lateral end of the bone, and is called the ***trapezoid line***.

The ***medial two-thirds*** is variably described as cylindrical or prismatic. It has four surfaces: (1) anterior, (2) posterior, (3) superior, and (4) inferior. These surfaces are not clearly marked off from each other. The large rough area presents on the inferior aspect of the bone near the medial end and forms part of the inferior surface. The middle-third of the inferior aspect shows a longitudinal groove, the depth of which varies considerably from bone to bone. This is the groove for subclavius (sometimes called the subclavian groove). In well-formed bones, a rough, depressed area can be seen medial to this groove. This is the impression for costoclavicular ligament.

The ***lateral*** or ***acromial end*** of the clavicle bears a smooth facet for articulation with the acromion of the scapula to form the acromioclavicular joint. The ***medial*** or ***sternal end*** articulates with the manubrium sterni and also with the first costal cartilage. The articular area is smooth and extends onto the inferior surface of the bone for a short distance. The uppermost part of the sternal surface is rough for ligamentous attachments.

The clavicle can easily be felt in the living person as it lies just deep to the skin in its entire extent. The sternal end of the bone forms a prominent bulge that extends above the upper border of the manubrium sterni.

Special Features of Clavicle

- Though it is a long bone, it differs from other long bones because:
  - It is the only long bone which lies horizontally.
  - It does not possess a medullary cavity.
  - It is the only long bone which ossifies in membrane.
  - It is the only long bone which ossifies from two primary centres
- It is the first bone to ossify and the last bone to complete ossification.
- It is subcutaneous in position and may be pierced by a cutaneous nerve (intermediate supraclavicular nerve).

Attachments of Various Structures (Figs 11.4 and 11.5)

Muscular Insertions

- The ***subclavius*** is inserted into the groove on the inferior surface of the shaft.
- The ***trapezius*** is inserted into the posterior border of the lateral one-third of the shaft.

Muscular Origins

- The clavicular head of the ***pectoralis major muscle*** arises from the anterior surface of the medial half of the shaft.
- The clavicular head of the ***sternocleidomastoid muscle*** arises from the medial part of the upper surface of the medial 2/3rds of the shaft.
- The lateral part of ***sternohyoid*** arises from the lower part of the posterior surface just near the sternal end.
- The ***deltoid*** arises from the anterior border of the lateral one-third of the shaft.

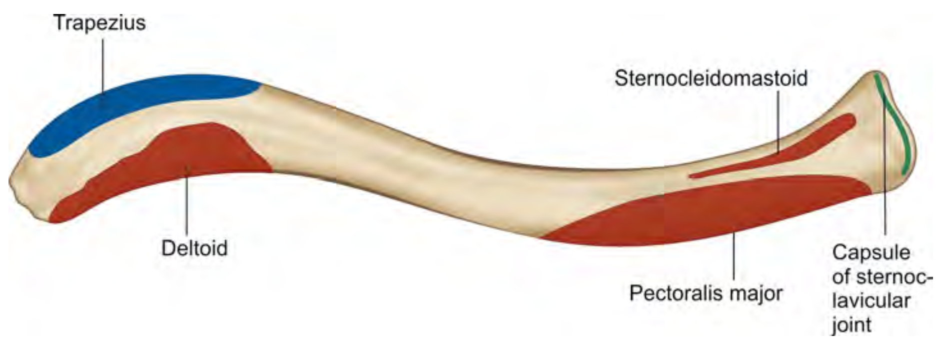


Fig. 11.4: Right c avicle showing attachments-seen from above

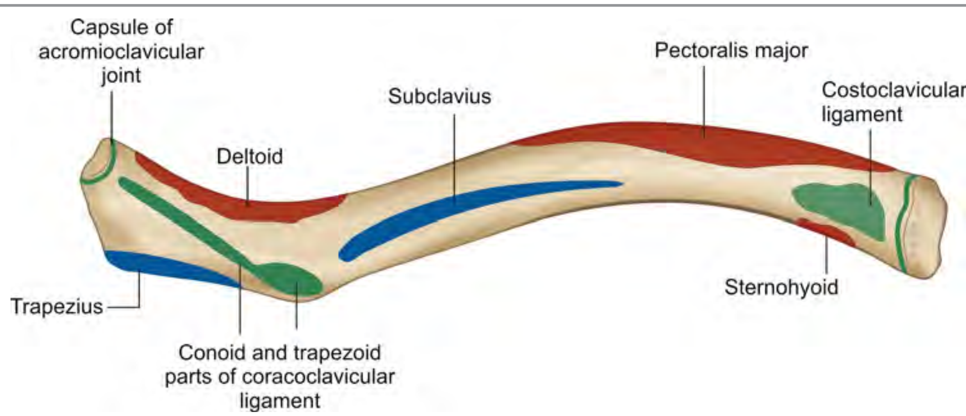


Fig. 11 5: Right clavicle showing attachments-seen f om below

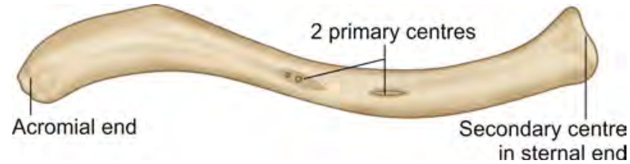


Fig. 11.6: Ossification of clavicle

Ossification

The clavicle is the first bone in the body to start ossifying. The greater part of the clavicle is formed by ***intramembranous ossification***. The sternal and acromial ends (Fig. 11.6) are preformed in cartilage. Two primary centres appear in the shaft during the 5th–6th weeks of foetal life and soon fuse with each other. The sternal end ossifies from a secondary centre that appears between 15 and 20 years of age, and fuses with the shaft by the age of 25 years. An additional centre may appear in the acromion.

SCAPULA

Other names: Shoulder blade, Blade bone

The ***scapula*** (Latin.scapule=shoulder blade, also meaning a spade) is a triangular plate of bone lying over the upper ribs in the back. It partly covers the 2nd to the 7th ribs. The bone gives attachments to muscles, forms the socket of the shoulder joint and enhances movements of the upper limb. It articulates with the clavicle and the humerus. The bone has a body and a spine. The body has two surfaces, three angles and three borders.

Clinical Correlation

- The sternal end of clavicle is the growing end.
- The nutrient artery to clavicle arises from the clavicular branch of the acromioclavicular artery.
- ***Fractures of the clavicle:*** Most of the fractures of the clavicle are caused by indirect violence. The bone is most commonly fractured at the junction of its middle and lateral one-thirds, as it is the weakest point of the bone. In this fracture, the outer fragment is pulled downwards by the weight of the upper limb and medially by the pectora is major. The inner segment is pulled upwards by the sternocleidomastoid. Less commonly, the clavicle can be fractured near its lateral end The slender and thin clavicle of a neonate may be fractured during birth, as the foetus passes through the birth canal. In neonates and young children, fracture of the bone is often incomplete, leading to what is called a '***greenstick fracture***'. One part of the bone may be broken but the other side is bent. The bone resembles the bent branch of a tender sapling (green stick) which is not disconnected but is merely hanging sharp.
- ***Failure of fusion of ossification centres:*** When the two ossification centres of the bone do not fuse, the medial and lateral parts of the bone remain separate. Th s is a congenital deformity and should not be mistaken for a fracture. This condition is usually bilateral.

Added Information

- The clavicle, though readily palpable, is not strictly subcutaneous. It is subplatysmal. The thin elastic sheet of platysma intervenes between the skin and the clavicle. It is the platysma that allows the skin to move freely over the clavicle. Platysma is superficial to the supraclavicular nerves which descend in front of the bone.
- The bone is so named because it rotates like a key would do within the keyhole of a lock, during movements of the shoulder.
- The anterior aspect of the bone has a linear strip that is devoid of any muscular attachment. This strip lies between the attachments of sternocleidomastoid and trapezius above and the pectoralis major and deltoid below.
- Due to the va ying features of the medial and lateral parts of the bone the medial two-thirds are regarded a long bone and the ateral third a flat bone.
- The epiphysis of the secondary centre of the clavicle is the last of the epiphysis of the long bones of the body to fuse.
- Variations in the sizes of the bones of the two sides are common. The right clavicle is usually shorter, though stronger.
- Animals which use the forelimbs (equivalent to the upper limbs) for support and locomotion do not need a clavicle; so, in such animals (examples like dogs, oxen and horses), the clavicle is absent or rudimentary. In animals which use the forelimb for grasping, climbing and flying (examples like primates, rodents and bats), the bone is well developed.
- The clavicle, as a strut (a strut is a crane-like rigid support), holds the scapula in position; and thus, in turn, holds the upper limb laterally, backward and a little upward. As a result, the limb in normal anatomical position, hangs behind the line of gravity and by its weight, maintains the erect posture. In fractures and deformities of the clavicle, the shoulders fall forward and medially, causing abnormalities of posture.
- The strut also keeps the upper limb away from the trunk, thus allowing free movements. The same strut action also helps the ribs getting elevated during deep inspiration.
- As one of the boundaries of the cervicoaxillary canal, the clavicle affords protection to the neurovascular bundle of the upper limb.
- The bone helps in transmission of shocks to the trunk from the upper limb.
- Structurally, the clavicle consists of spongy bone enclosed in a shell of compact bone.

Side Determination

- The greater part of the scapula consists of a flat triangular plate of bone called the ***body***. The upper part of the body is broad, representing the base of the triangle. The inferior end is pointed and represents its apex.

- The body has anterior (or costal) and posterior (or dorsal) surfaces. The anterior surface is smooth, but the upper part of the posterior surface gives off a large projection called the ***spine*** which stretches through the posterior surface from the medial to the lateral aspect.
- At its lateral angle, the bone is enlarged and bears a large shallow oval depression called the ***glenoid cavity*** which articulates with the head of the humerus.

The side to which a given scapula belongs can be determined from the points given above.

Orientation of the Scapula

The scapula is applied to the posterosuperior aspect of the thorax which itself is barrel shaped. So, the inferior part of the bone is posterior when compared to the superior part. The inferior angle, therefore, is behind the plane of the glenoid cavity. The lateral border runs downwards, medially and posteriorly. The glenoid cavity faces laterally, little upwards and forwards.

Body

As already mentioned, the body of scapula has two surfaces, three borders and three angles.

The ***two surfaces*** are— (1) the Costal and, (2) the Dorsal surfaces. The ***costal surface*** (Fig. 11.7) lies against the posterolateral part of the chest wall. It is somewhat concave from above downwards. It is marked by longitudinal ridges. Since it gives attachment to the subscapularis muscle, the costal surface (except for a thick bar-like portion near the lateral border) is also called the ***subscapular fossa***.

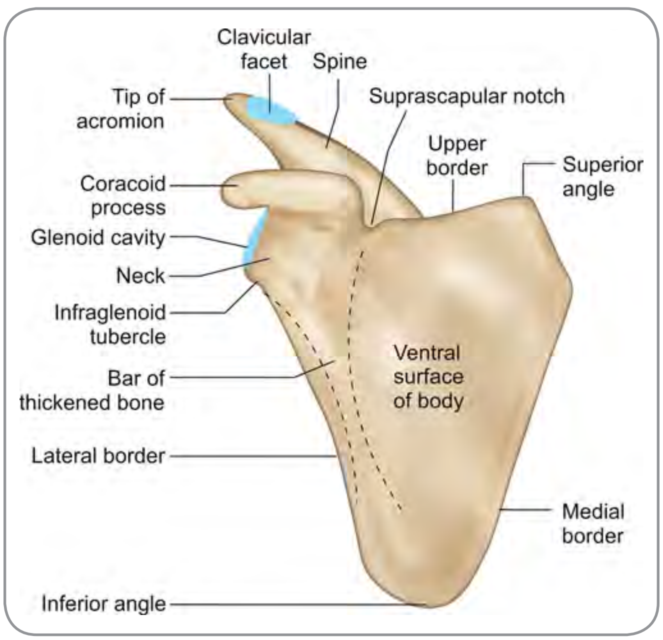


Fig. 11.7: Right scapula-seen from the front

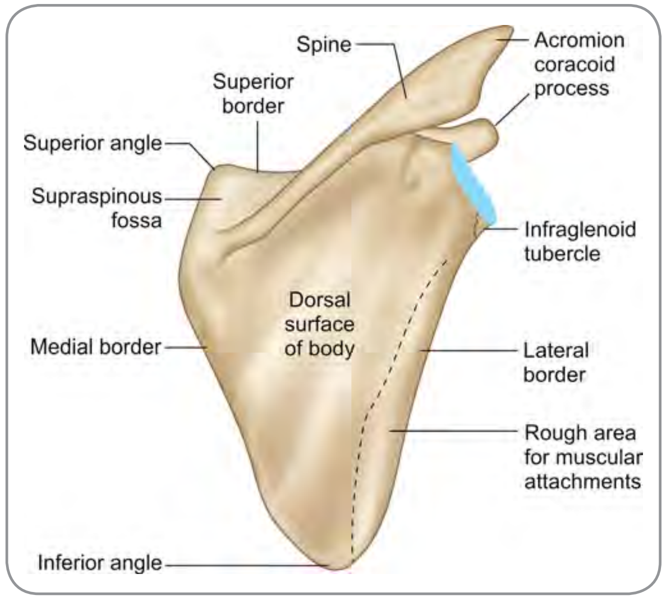


Fig. 11.8: Right scapula-seen from behind

The ***dorsal surface*** (Fig. 11 8) is slightly arched from above downwards and has longitudinal corrugations near the lateral border. It gives off a large projection called the spine of scapula. The area above the spine, along with the upper surface of the spine forms the ***supraspinous fossa***. The area below the spine, along with the lower surface of the spine forms the ***infraspinous fossa***. The supraspinous and infraspinous fossae communicate with each other through the ***spinoglenoid notch*** that lies on the lateral side of the spine. The dorsal surface is otherwise called the ***dorsum scapulae***.

The body of scapula has ***three angles***— (1) superior, (2) inferior, and (3) lateral angles. The ***superior angle*** is at the junction of the superior and the medial borders. It is thin and acute. The ***inferior angle*** is at the junction of the medial and the lateral borders. It is thick and rounded. The ***lateral angle*** is at the junction of the superior and the lateral borders and is large and truncated. Since it bears the glenoid fossa, it is also called the ***glenoid angle***.

There are ***three borders***, namely (1) medial, (2) lateral, and (3) superior borders.

The ***superior border*** passes laterally and downwards from the superior angle to the lateral angle Since there is no strain on this border and it does not give attachment to any bulky muscle, it is thin and sharp. At the lateral end, it is separated from the glenoid cavity by the root of the coracoid process. A deep ***suprascapular notch*** (also called the ***scapular notch***) is seen close to the lateral end of the superior border The ***medial border***, otherwise called the ***vertebral border***, extends from the superior to the inferior angle. It is arched and thicker than the superior border, because it gives attachments to muscles.

The ***lateral border***, otherwise called the ***axillary border,*** runs from the lateral to the inferior angle. The part of the body adjoining the lateral border is thickened to form a longitudinal bar of bone, called the ***strengthening bar***.

Glenoid Cavity

The ***glenoid cavity*** (Greek.glene=shallow) is a shallow articular socket for the head of humerus present at the lateral angle of the scapula. Its anterior margin is grooved by the subscapularis tendon and so the glenoid gets a pear shape Just below the cavity, the lateral border shows a rough raised area called the ***infraglenoid tubercle***. Immediately above the glenoid cavity is a rough area ca led the ***supraglenoid tubercle***. The region of the glenoid cavity is often regarded as the head of the scapula. The slightly constricted area immediately medial to it constitutes the ***neck***.

Processes of the Scapula

The scapula is usually described to have ***three processes*** These are (1) the spinous process (often plainly called the spine), (2) the acromion process (or simply the acromion), and (3) the coracoid process.

- The ***spinous process*** is a large triangular projection from the posterior surface of the body. The apex of the triangle is at the medial end, and the base is laterally placed and forms the lateral border of the spine. The anterior border of the spine is attached to the dorsal surface; the posterior border is free and is greatly thickened to form the ***crest of the spine***. The medial end of the spine (apex) lies near the medial border of the scapula and is often referred to as the ***root of the spine***. The lateral border is free, broad and forms the medial boundary of the ***spinoglenoid notch*** (Fig. 11.9) (also called the ***great scapular notch***). The crest is broad and flat; it has upper and lower lips with the intervening area being subcutaneous. The spine, as already noted, divides the dorsal surface into supraspinous and infraspinous fossae.
- The ***acromion*** (Greek.akros=point, omos=shoulder, acromios=point of the shoulder) is continuous with the lateral end of the spine and is, in fact, a projection of the latter. It forms a projection that is directed forwards and partly overhangs the glenoid cavity. It has lateral and medial borders which meet anteriorly at the tip of the acromion. The lateral border meets the crest of the spine at a sharp angle (usually a right angle) as termed the ***acromial angle***. The medial border shows the presence of a small oval facet for articulation with the lateral end of the clavicle. The acromion also has upper and lower surfaces; the lateral border of the spine fades into the lower surface. The upper surface faces posterosuperiorly and is subcutaneous.
- The ***coracoid process*** (Greek.korax, korone=crow) is shaped like a bent finger. The root of this process is attached to the body of the scapula just above the glenoid cavity. The lower part of the root is marked by the supraglenoid tubercle. The tip portion which is also called the horizontal part is directed forwards, laterally and a little downwards.

Attachments of Various Structures

Muscular Insertions

- The ***trapezius*** is inserted into the upper border of the crest of the spine, and into the medial border of the acromion
- The ***serratus anterior*** is inserted into the **costal surface** along the **medial border** (Fig. 11.10)
  - The first digitation of the muscle is inserted from the superior angle to the root of the spine.
  - The next two or three digitations are inserted into a narrow line along the medial border.
  - The lower 4 or 5 digitations are inserted into a large triangular area over the inferior angle.

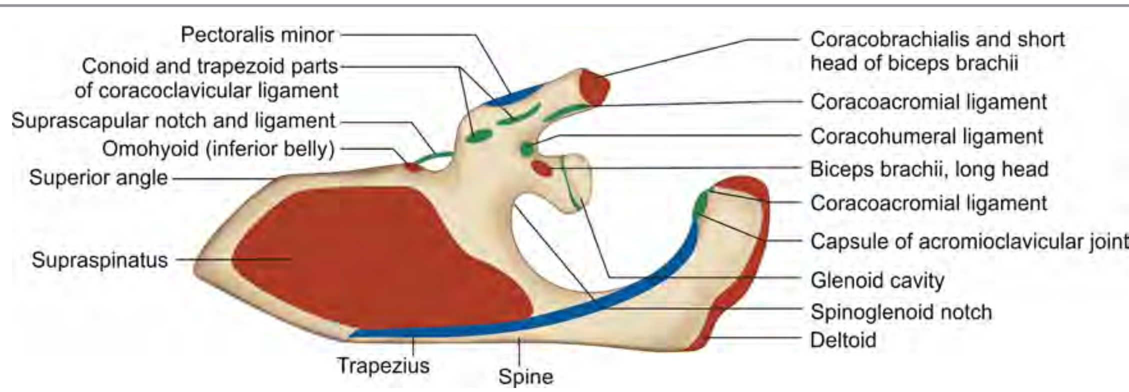


Fig. 11.9: Right scapula-superior aspect

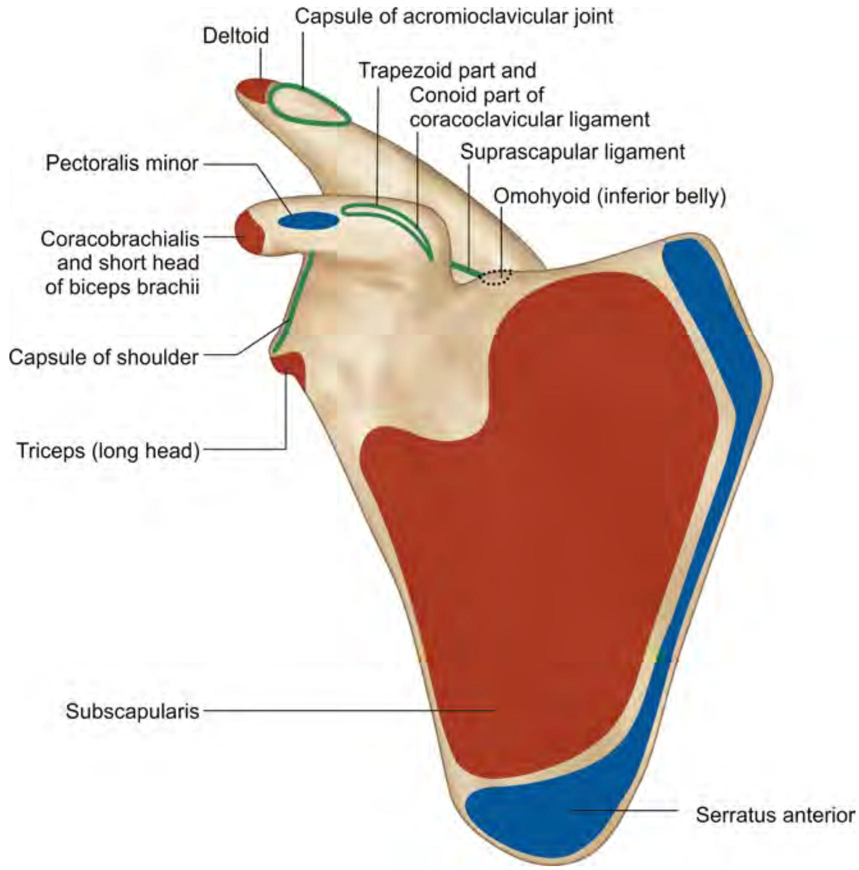


Fig. 11 10: Right scapula showing attachments-seen from the front

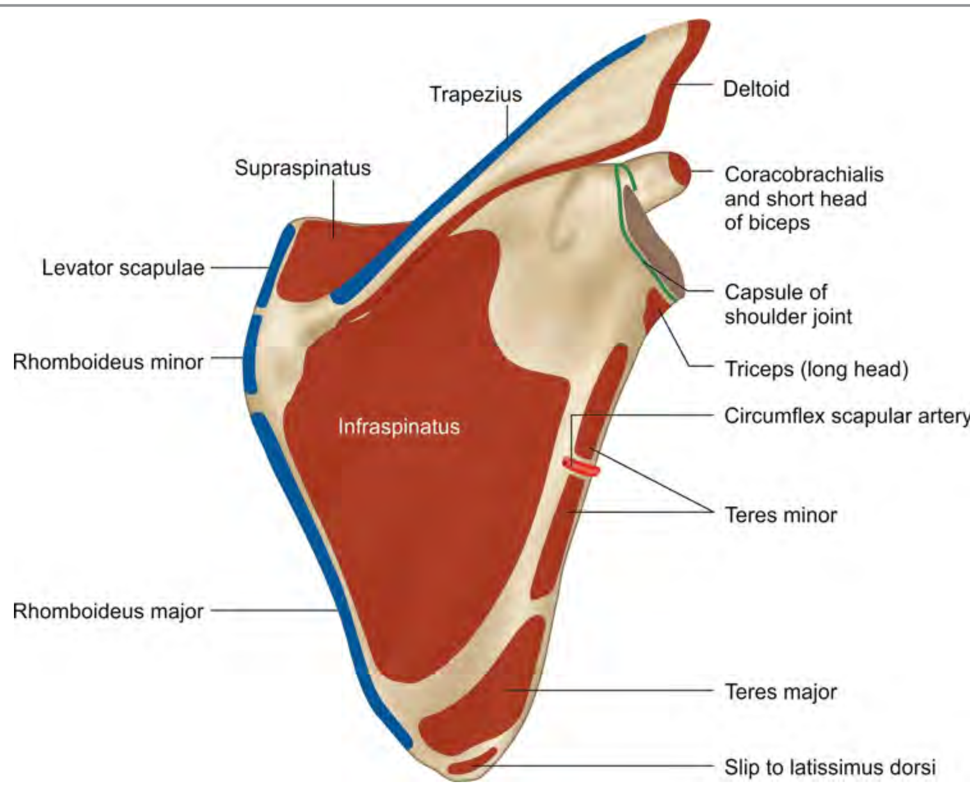


Fig. 1 .11: Right scapula showing attachments-seen from behind

- In the **dorsal** aspect of the medial border:
  - The ***levator scapulae*** (Fig. 11.11) is inserted into a narrow strip, extending from the superior angle to the level of the root of the spine.
  - The ***rhomboideus minor*** is inserted opposite the root of the spine.
  - The ***rhomboideus major*** is inserted from the root of the spine to the inferior angle.

Muscular Origins

- The short head of the ***biceps brachii*** arises from the lateral part of the tip of the coracoid process; and the long head from the supraglenoid tubercle.
- The ***coracobrachialis*** arises from the medial part of the tip of the coracoid process (Fig. 11.12).
- The long head of the ***triceps*** arises from the infraglenoid tubercle.
- The inferior belly of the ***omohyoid*** arises from the upper border near the suprascapular notch.
- The ***subscapularis*** arises from the whole of the costal surface, except for a small part near the neck.
- In the **dorsal** aspect of the **lateral border**: (Fig. 11.12)
  - The ***teres minor*** arises from the upper two-thirds of the rough strip.
  - The ***teres major*** arises from the lower one-third of the rough strip extending over the inferior angle.
- The ***supraspinatus*** arises from the medial two-thirds of the supraspinous fossa, including the upper surface of the spine.
- The ***infraspinatus*** arises from the greater part of the infraspinous fossa, except near the lateral border and a part near the neck.

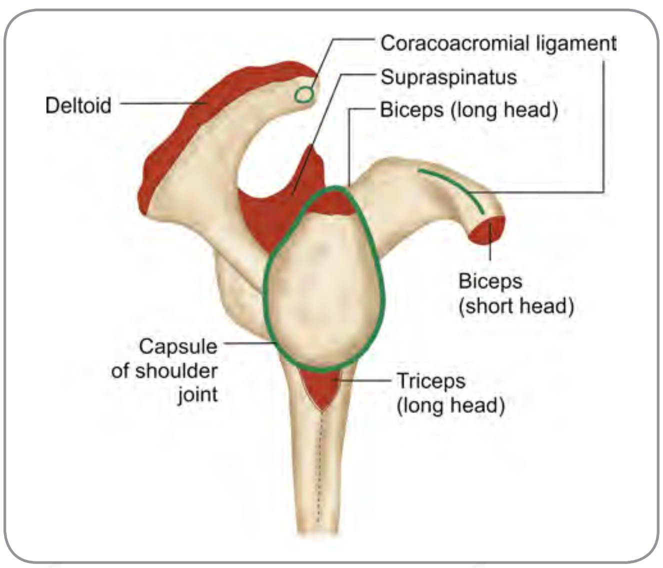


Fig. 11.12: Right scapula showing attachments-seen from the lateral side

- The ***latissimus dorsi*** receives a small slip from the dorsal surface of the inferior angle.

Attachments of other Structures

- The ***capsule of the shoulder joint*** and the ***glenoidal labrum*** are attached to the margins of the glenoid cavity. In the upper part of glenoid cavity, the attachment of the capsule extends above the supraglenoid tubercle which makes the origin of the long head of the biceps intracapsular, i.e., within the capsule of the shoulder joint.
- The ***suprascapular ligament*** (also called the superior transverse ligament) bridges across the suprascapular notch and converts it into a foramen which transmits the suprascapular nerve. The suprascapular vessels lie above the ligament.
- The spinoglenoid notch is often converted into a foramen by the ***spinoglenoid ligament***. The suprascapular nerve and artery enter the infraspinous fossa from the supraspinous fossa through the spinoglenoid notch or the foramen, if present.

Clinical Correlation

- The nutrient artery is a branch of the suprascapular artery.
- ***Vertebral levels:*** Different parts of the scapula correspond to different vertebral levels and these can be used as landmarks The superior angle corresponds to T2 spine, the root of spine to T3 spine and the inferior angle to T7 spine.
- ***Triangle of auscultation:*** This is marked in relation to the scapula. The medial border of this triangle is the lateral border of trapezius, the lateral border is the lower part of the medial border of scapula and the inferior border is the upper line of latissimus dorsi.
- Various neurovascular structures are related to different parts of scapula. The suprascapular vessels and nerve are related to the superior border and the spinoglenoid area. The circumflex scapular branch of the subscapular artery turns around the lateral border between the two sets of fibres of teres minor and reaches the posterior aspect. The deep branch of the transverse cervical artery is related to the medial border.
- The suprascapular nerve can be entrapped at the suprascapular foramen or the spinoglenoid foramen.
- ***Fractures of the scapula*** (Fig. 11.13) are uncommon. They can occur in automobile accidents. Usual sites of fracture are:
  - Body of the scapula
  - Fracture through the neck
  - Fracture of the acromion process
  - Fracture of the coracoid process.
- ***Sprengel's shoulder:*** (also called ***scapula elevata***) is a condition in which the scapula is placed higher than normal.
- ***Winging of the scapula:*** (also called scapula alata) is a condition in which the medial border of the scapula is lifted off the chest wall. It is caused by paralysis of the serratus anterior muscle.
- ***Variations*** in the shape and size of scapula can occur.
- ***Non-union of epiphysis*** usually involves one of the acromial centres.

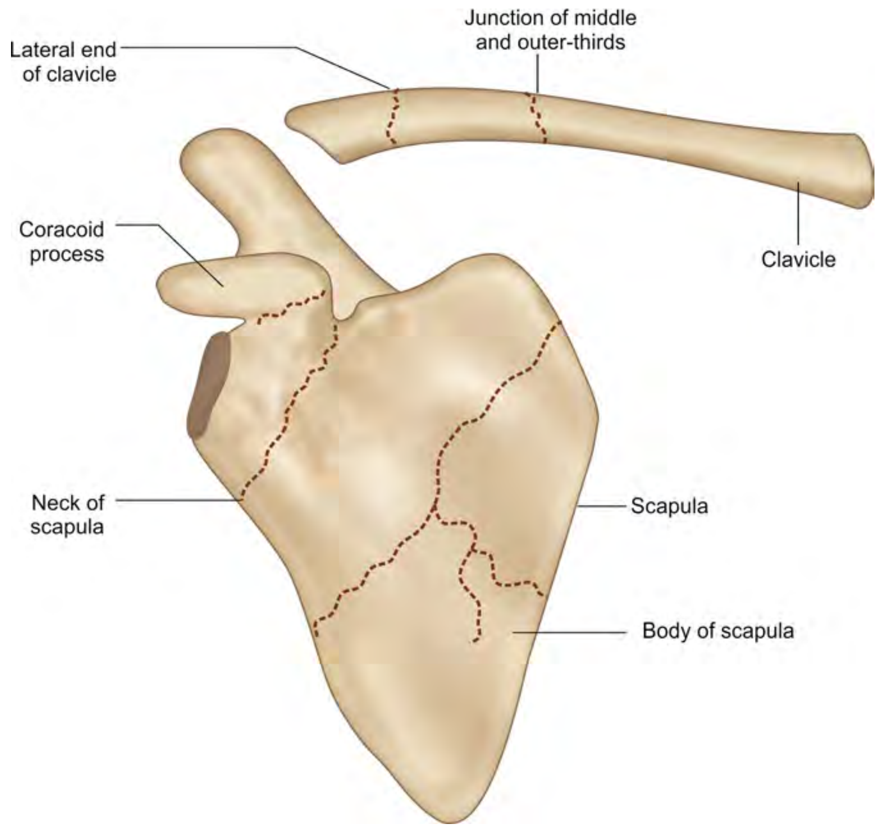


Fig. 11.13: Fractures of scapula and clavicle

Added Information

- The lower end of the scapula is felt easily and is used as a landmark.
- The meeting point of the apex of the spine and the medial border of scapula has a small triangular smooth area which is covered by the fibres of trapezius muscle.
- The same smooth triangle can be readily felt at the level of T3 spine and is used as a landmark.
- The acromial angle is also felt easily and used as a measuring point for chest dimensions.
- In some cases, the acromion is attached to the spine by cartilage or by a synovial joint (spinoacromial joint).
- Some authors define a primary centre for the coracoid process because of the appearance of such a centre before birth.
- The bony parts of scapula may get absorbed in old age with only the periosteum remaining.
- The crest of the spine is clinically referred to as the posterior border of the bone.
- The medial most point of attachment of deltoid fibres on the lower lip of the crest is prominent and is referred to as the deltoid tubercle
- When the scapular body is in anatomical position, the medial border runs parallel and about 5 cm lateral to the thoracic vertebrae.
- The strengthening bar prevents buckling of the scapula.

contd...

Added Information *contd...*

- The scapula forms the scapulothoracic joint with the thoracic wall. This is a physiological joint where movements occur between, on one side, the scapula and the associated muscles and, on the other, the thoracic wall This is not an anatomical joint where movements occur between bony elements.
- The scapulothoracic joint is where the movements of scapular elevation-depression, scapular protraction-retraction and scapular rotation occur.

Ossification

The scapula has one primary centre and seven secondary centres The primary centre appears in the region of the body during the 8th week of foetal life. The spine is ossified by an extension from this centre. The greater part of the coracoid process is ossified from a secondary centre that appears in the first year. The remaining secondary centres, which appear about the age of puberty, are one for the subcoracoid area including the glenoid, two for the acromion, one for the medial border and one for the inferior angle. All the secondary centres fuse between the 18th and the 22nd years of age.

HUMERUS

Other names: Arm bone, Laughing bone, Funny bone

The humerus (Latin. humer=shoulder) is the bone of the arm and extends from the shoulder to the elbow. It is a long bone with a cylindrical central part ***shaft***, and an enlarged ***upper*** and ***lower ends*** (Figs 11.14 and 11.15).

Side Determination

- The upper end is marked by the presence of a large rounded head. The lower end is expanded
- The head is directed medially and so helps to decide the medial and lateral sides
- The anterior aspect of the upper end shows a prominent vertical groove called the ***intertubercular sulcus***.

From the above-mentioned information, the side of a given humerus can be determined.

Upper End (Fig. 11.16)

The upper end has a hemispherical head, an ill-defined neck, two distinct tubercles and a deep groove between the tubercles.

The ***head*** is rounded (actually forms a third of a sphere) and has a smooth convex articular surface. It is directed medially, and also somewhat backwards and upwards. The articular surface articulates with the glenoid cavity of the scapula to form the shoulder joint. It may be noted that the articular area of the head is much greater than that of the glenoid cavity.

There are two distinct regions of the upper end of the humerus which are referred to as the ***neck***. The junction of the head with the rest of the upper end is called the ***anatomical neck*** and is seen as a slightly constricted, narrow strip that encircles the head at the edge of the

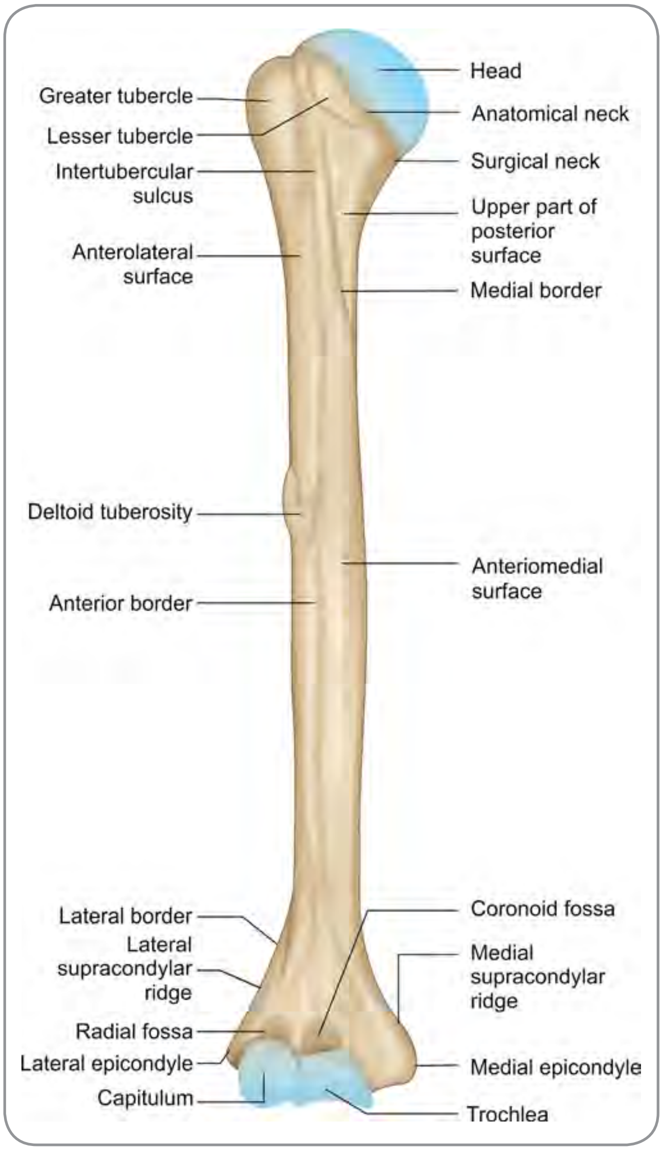


Fig. 11.14: Right humerus-seen from the front

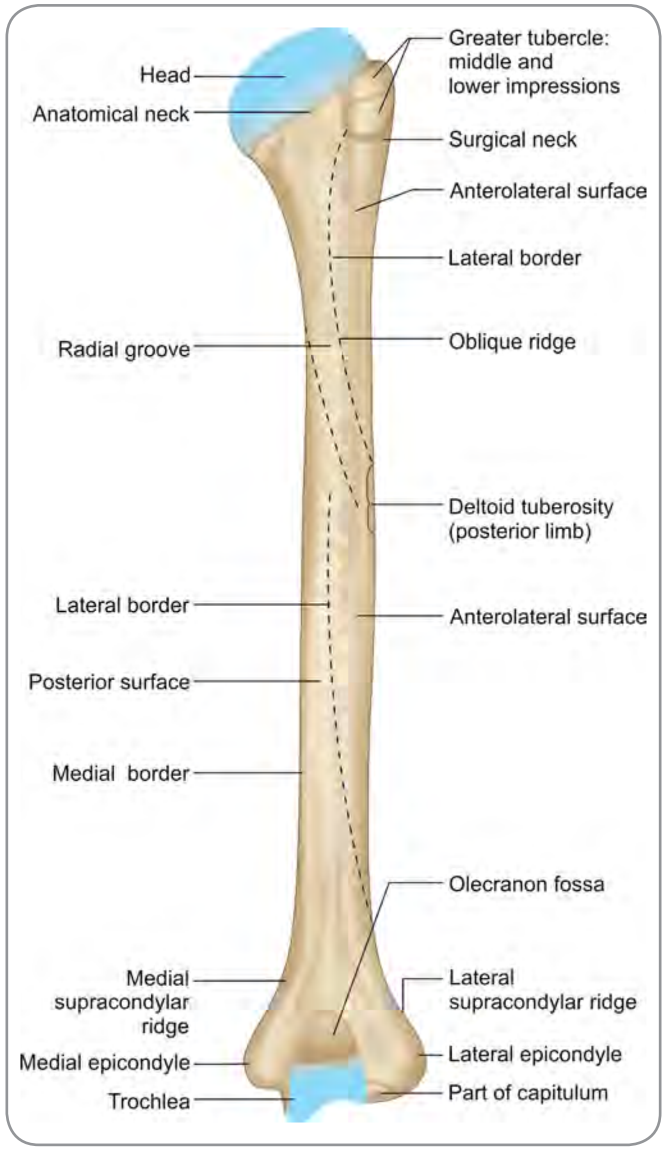


Fig. 11 15: Right humerus-seen from behind

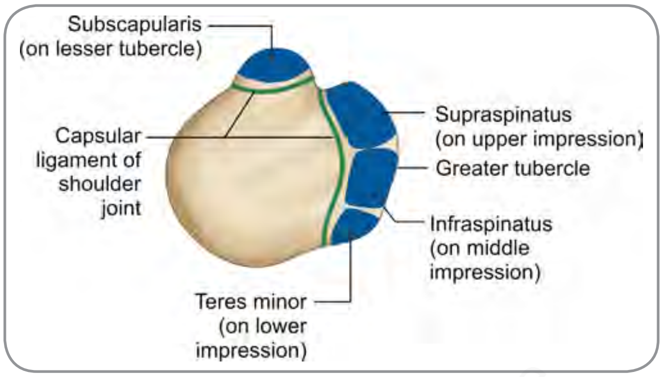


Fig. 11 16: Upper end of right humerus showing attachments seen from above

articular surface. The junction of the upper end with the shaft is called the ***surgical neck***. This is the region that narrows down from the head and the tubercles to join the shaft. Apart from these two, the line corresponding to the junction of epiphysis and metaphysis is called the ***morphological neck***. It is represented by a line 0.5 cm above the surgical neck.

The two prominences in the upper end are called ***the greater*** and ***lesser tubercles*** (or tuberosities). These two tubercles are separated by the deep groove called the ***intertubercular sulcus*** (also called the bicipital groove) which is seen as a vertical furrow on the anterior aspect of the upper end. The ***greater tubercle*** is present on the lateral aspect of the upper end. Therefore, parts of it can be seen from both the anterior and posterior aspects. Three areas (or impressions) of muscular attachments are present on the tubercle. The uppermost of these is on the superior aspect, the lowest on the posterior aspect, and the middle is in between them. The ***lesser tubercle*** is on the anterior aspect of the bone medial to the intertubercular sulcus and lateral to the head. It has a smooth upper part and a rough lower part. The ***intertubercular sulcus*** lies between the two tubercles and passes down to the shaft. The anterior part of the greater tubercle continues down as the crest of the greater tubercle and forms the lateral lip of the sulcus. The medial part of the lesser tubercle continues down as the crest of the lesser tubercle and forms the medial lip of the sulcus.

Shaft

The ***shaft*** of the humerus has three borders and three surfaces.

The ***three borders*** are called the (1) anterior, (2) medial and (3) lateral borders. These are readily identified in the lower part of the bone. When traced upwards, the ***anterior border*** becomes continuous with the anterior margin of the greater tubercle (or crest of the greater tubercle, or lateral lip of the intertubercular sulcus). The ***medial border*** is indistinct, but can be traced to the lower end of the lesser tubercle and to its sharp lateral margin (cres of the lesser tubercle, or medial tip of the intertubercular sulcus). The lower part of the ***lateral border*** can be seen from the front, but its upper part runs upwards on the posterior aspect of the bone.

The three borders of shaft divide it into three surfaces, namely the anterolateral, anteromedial and posterior surfaces.

- The ***anterolateral surface*** lies between the anterior and lateral borders
- The ***anteromedial surface*** lies between the anterior and medial borders
- The ***posterior surface*** lies between the medial and lateral borders

In the anterolateral surface, a V-shaped rough area called the ***deltoid tuberosity*** is present near the middle. The anterior limb of the tuberosity lies along the anterior border of the shaft while the posterior limb lies above the lower part of the radial groove. When the shaft is observed from behind, a broad and shallow groove called the ***radial groove*** (also called the ***spiral groove***, since it appears to spiral around the shaft) running downwards and laterally across the upper parts of the posterior and anterolateral surfaces can be seen. The radial groove interrupts the lateral border of the shaft. The part of the lateral border below the groove is indistinct, but the part of the border above the groove can be traced to the posterior part of the greater tuberosity. The upper margin of the radial groove is formed by a roughened ridge that runs obliquely across the shaft. The lower end of the ridge is continuous with the posterior limb of the deltoid tuberosity. The shaft between the radial groove and the lower end of the bone widens out below and is smooth.

Lower End

The lower end of the humerus is irregular in shape, and is sometimes referred to as the ***condyle***. It is flattened from backwards, expanded from side to side and bent slightly forwards. It has articular and non-articular parts As the lower end expands both medially and laterally, the prominences made out of such expansions form the ***medial*** and the ***lateral epicondyles***. The medial epicondyle is the larger and more projecting of the two. The middle portion of the distal edge of the bone can be seen to be pulley-shaped and is called the ***trochlea***. It articulates with the upper end (trochlear notch) of the ulna. Lateral to the trochlea is the rounded convex projection called the ***capitulum*** (Latin.capitulum=small head) that articulates with the head of radius. The capitulum can be seen on the anterior and inferior aspects of the bone but does not extend posteriorly. The bone above the trochlea is thinned out and so depressions can be seen both on the anterior and posterior aspects. Two depressions are

seen on the anterior aspect; the medial one above the trochlea is larger and is called the ***coronoid fossa*** and the lateral one above the capitulum is smaller and is called the ***radial fossa*** (parts of the coronoid process of ulna and the head of radius lie in these depressions respectively when the elbow is fully flexed). The posterior depression is the ***olecranon fossa***. It lodges the olecranon process of the ulna when the elbow is fully extended. The medial margin of the trochlea projects downwards much below the level of the capitulum, and of the epicondyles.

The lowest parts of the medial and lateral borders of the humerus form sharp ridges called the ***medial*** and ***lateral supracondylar ridges***. Their lower ends terminate in the ***medial*** and ***lateral epicondyles***. The posterior aspect of the medial epicondyle is smooth and has a shallow sulcus. The posterior aspect of the lateral epicondyle is smooth and subcutaneous and, therefore, is felt easily.

Attachments of Various Structures

Muscular Insertions (Figs 11.17 and 11.18)

- The ***supraspinatus*** is inserted into the upper impression on the greater tubercle.
- The ***infraspinatus*** is inserted into the middle impression on the greater tubercle.
- The ***teres minor*** is inserted into the lower impression on the greater tubercle.
- The ***subscapularis*** is inserted into the lesser tubercle.
- The ***pectoralis major*** is inserted into the lateral tip of the intertubercular sulcus.
- The ***latissimus dorsi*** is inserted into the floor of the intertubercular sulcus.
- The ***teres major*** is inserted into the medial tip of the intertubercular sulcus.

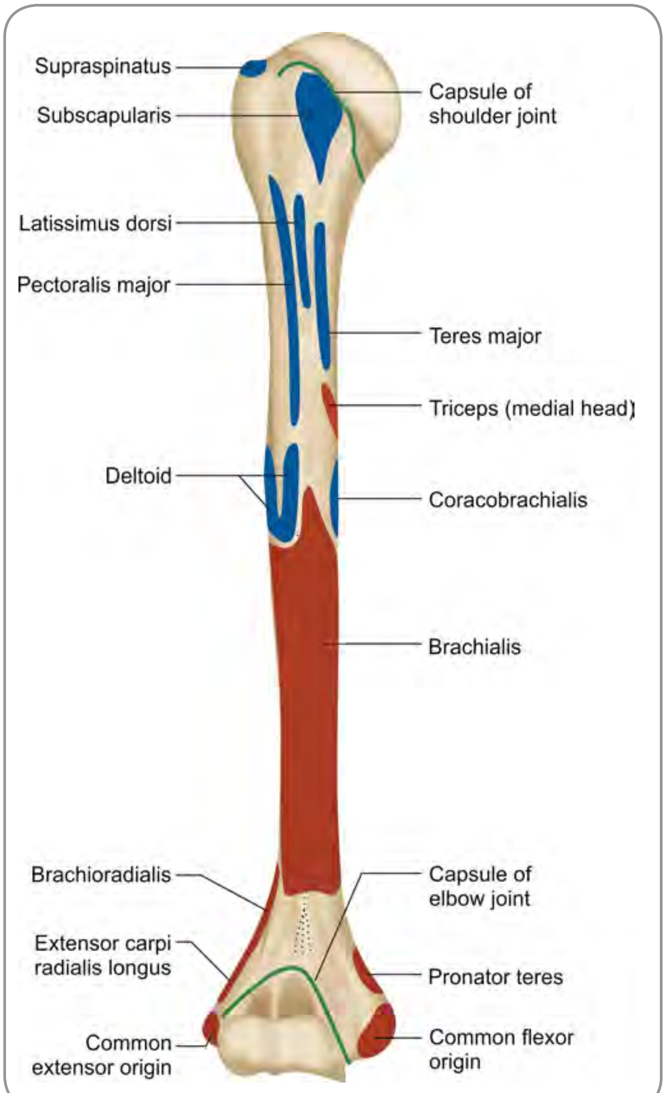


Fig. 11.17: Right humerus showing attachments-seen from the front

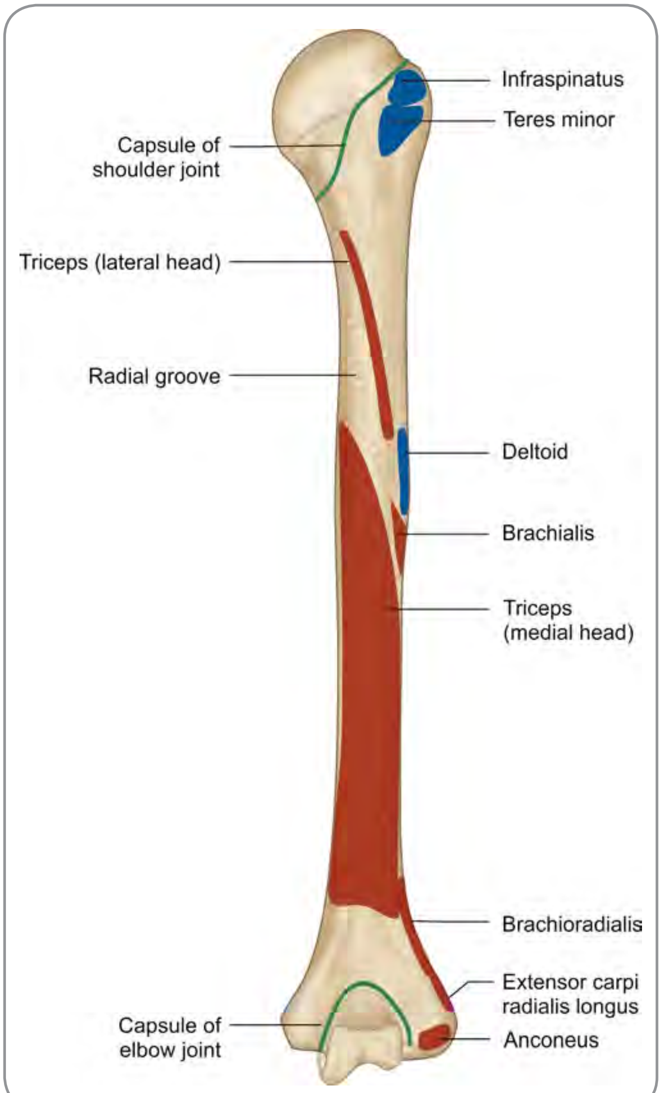


Fig. 11.18: Right humerus showing attachments-seen from behind

- Of the three insertions into the intertubercular sulcus, that of the pectoralis major is the most extensive, and that of the latissimus dorsi is the shortest.

- The ***deltoid*** is inserted into the deltoid tuberosity.
- The ***coracobrachialis*** is inserted into the rough area on the middle of the medial border.

Muscular Origins

- The ***brachialis*** arises from the lower halves of the anteromedial and anterolateral surfaces of the shaft. Part of the area of origin extends onto the posterior aspect.
- The ***pronator teres*** (humeral head) arises from the anteromedial surface, near the lower end of the medial supracondylar ridge.
- The ***brachioradialis*** arises from the upper two-thirds of the lateral supracondylar ridge.
- The ***extensor carpi radialis longus*** arises from the lower one-third of the lateral supracondylar ridge.
- The ***superficial flexor muscles*** of the forearm arise from the anterior aspect of the ***medial epicondyle***. This origin is called the ***common flexor origin.***
- The ***common extensor origin*** for the superficial extensor muscles of the forearm is located on the anterior aspect of the ***lateral condyle.***
- The lateral head of the ***triceps*** arises from the oblique ridge on the upper part of the posterior surface, just above the radial groove. The medial head of the muscle arises from the posterior surface below the radial groove. The upper end of the area of origin extends onto the anterior aspect of the shaft.
- The ***anconeus*** arises from the posterior surface of the lateral epicondyle (Fig. 11.18).

Attachments of Other Structures

- The ***capsular ligament of the shoulder joint*** is attached on the anatomical neck.
  On the medial side, the line of attachment dips down by about a centimetre to include a small area of the shaft within the joint cavity. The line of attachment of the capsule is interrupted at the intertubercular sulcus to provide an aperture through which the tendon of the long head of the biceps leaves the joint cavity.
- The ***capsular ligament of the elbow joint*** is attached to the lower end of the bone.
  - Anteriorly the line of attachment reaches the upper limits of the radial fossa and the coronoid fossa.
  - Posteriorly the line reaches the upper limit of the olecranon fossa.

  These fossae therefore lie within the joint cavity.
- The medial and lateral epicondyles give attachment to the ***ulnar*** and ***radial collateral ligaments*** respectively.

Important Relations

- The intertubercular sulcus lodges the tendon of the long head of the biceps brachii. The ascending branch of the anterior circumflex humeral artery also lies in this sulcus.
- The surgical neck of the bone is related to the axillary nerve and to the anterior and posterior circumflex humeral vessels.
- The radial nerve and the profunda brachii vessels lie in the radial groove between the attachments of the lateral and medial heads of the triceps.
- The ulnar nerve crosses behind the medial epicondyle, lying on a shallow sulcus.

Clinical Correlation

- The upper end is the growing end and the nutrient foramen is directed to the elbow.
- The main nutrient artery is a branch of the brachial artery; a branch of the profunda brachii artery may also enter the bone.
- **Fractures of the humerus (Fig. 11 19).**

Fractures of humerus are comparatively common and can occur at almost any level.

- Among the various sites, fracture of shaft of humerus can occur through the surgical neck, through the middle of its shaft and/or just above the lower end (supracondylar fracture). Since the surgical neck is weaker than more proximal and distal regions of the bone, fracture is common in the surgical neck.
- Other fractures that can be seen are through the greater tuberosity, condyles (usually lateral) or through an epicondyle (usually medial).
- In children, the most common fracture is ***supracondylar***. Fractures through the neck are common in old women. Fracture through the middle of the shaft usually occurs in adults.
- Avulsion fracture of the greater tubercle is seen in the older age group. The muscles attached to the humerus cause a medial rotation
- ***Nerves that can be damaged:***

Humerus is related to several nerves and these may be damaged in fracture.

- Fracture through the surgical neck of the humerus can damage the axillary nerve (the posterior circumflex humeral artery may also be damaged, but such damage is usually rare)
- Fracture through the middle of the shaft can damage the radial nerve (which lies in the radial groove).
- In supracondylar fracture, the median nerve can be injured, and there is danger of damage to the brachial artery as well.
- The ulnar nerve can be damaged in a fracture of the medial epicondyle.
- **Non-union**

Humerus has a poor blood supply at the junction of its upper and middle-thirds. Fractures at this site may, therefore, heal poorly, resulting in delayed union or in non-union.

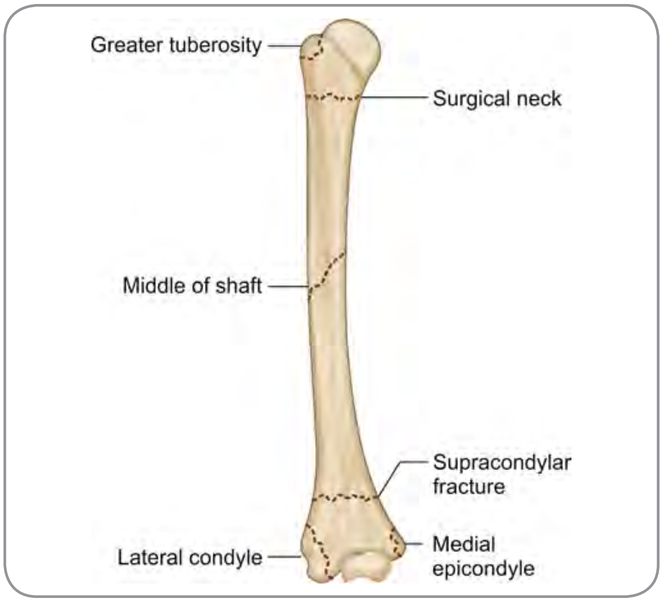


Fig. 11.19: Fractures of humerus

Ossification

A single primary centre appears in the shaft during the 8th foetal week. The greater part of the bone is formed from this centre

Secondary centres at the upper end appear as follows:

- ***Head:*** Early in the first year
- ***Greater tubercle:*** Second year
- ***Lesser tubercle:*** Fifth year

These three parts fuse with each other in the sixth year to form a single epiphysis for the upper end that fuses with the shaft around 18 to 20 years of age.

Secondary centres at the lower end appear as follows:

- ***Capitulum:*** First year
- ***Medial part of the trochlea:*** Ninth or tenth year
- ***Lateral epicondyle:*** Twelfth year

These fuse to form a single epiphysis which fuses with the shaft around 15 years of age.

A separate centre appears in the medial epicondyle around the fifth year; and fuses with the shaft around the twentieth year.

Added Information

- The humerus is often dubbed as the '***laughing bone'*** due to the similarity in the pronunciation of its name and the English word 'humorous'. However, the epithet is justified by the tickling sensation one feels when the medial epicondyle of the humerus is tapped due to the stimulation of the ulnar nerve passing behind it.
- The greater and lesser tubercles are separated from the head by the anatomical neck, from the body by the surgical neck and from each other by the intertubercular sulcus.
- The greater tubercle projects laterally beyond the acromion and, therefore, gives the roundness to shoulder.

contd...

Added Information *contd...*

- The lesser tubercle is directed straightforward in the anatomical position.
- A strengthening bar of bone extends from between the coronoid and radial fossae to the deltoid tuberosity and continues upwards into the crest of the greater tubercle. This strengthening bar causes the lower half to have a triangular cross-section; the anterior aspect slopes medially and laterally.
- A marked variation seen is the presence of a supracondylar process. It is a hooked process found about 3 to 4 cm above the medial epicondyle and connected to it by a fibrous band (Struther's ligament). The median nerve and the brachial vessels may pass through the foramen thus formed.
- Plate of bone above the trochlea may be fenestrated or absent, thus leading to the formation of supratrochlear foramina

RADIUS

Other names: Rod bone, Wheel bone

The radius (Latin.radion=rod, ray) is the lateral of the two bones of the forearm. It extends from the elbow to the wrist. Since it does not overlap the humerus, it is shorter than the ulna. It is a long bone with a shaft and two ends.

Side Determination

- The upper end bears a disc-shaped head, while the lower end is much enlarged.
- The shaft is convex laterally and has a sharp medial border.
- The lower end is smooth anteriorly but has numerous ridges and grooves on its posterior aspect.

From the above given information, the side of a given radius can be made out (Figs 11.20 and 11.21).

Upper End

The ***upper end*** of the bone consists of a head, a neck and a tuberosity The ***head*** is disc-shaped. Its upper surface is concave and articulates with the capitulum of the humerus. The circumference of the head (representing the edge of the disc) is also smooth and articular. The medial part of this edge articulates with a notch on the ulna to form the superior radioulnar joint. The remaining part of the edge is encircled by the annular ligament which holds it against the notch but still allows it to rotate freely. The region just below the head is constricted to form the ***neck***. It is smooth with a few vascular foramina. Just below the medial part of the neck, there is an elevation called the ***radial tuberosity*** The tuberosity is rough in its posterior part and is smooth anteriorly.

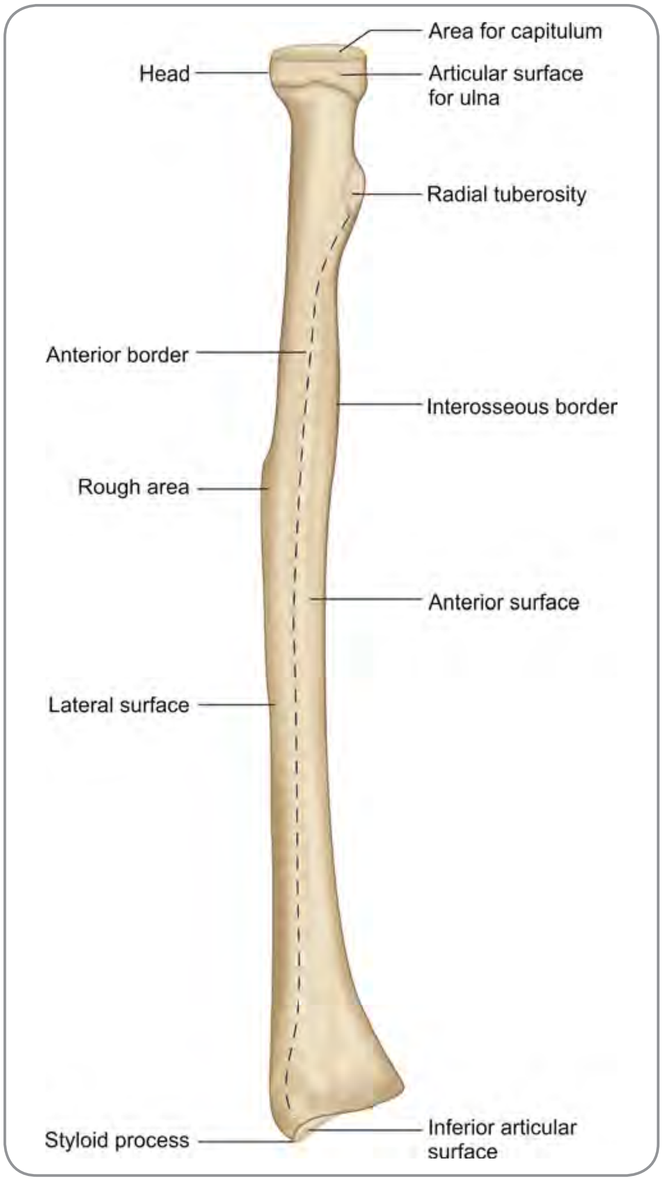


Fig. 11.20: Right radius-seen from the front

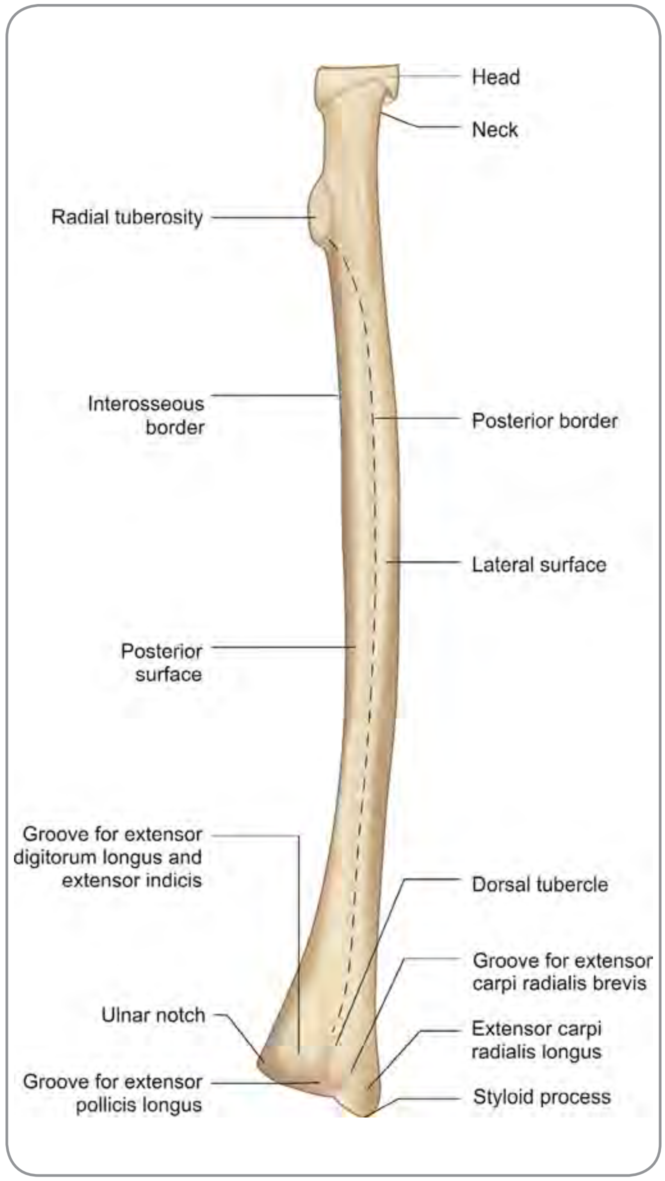


Fig. 11.21: Right radius-seen from behind

Shaft

The shaft of the radius is round near the neck but becomes triangular in section lower down It has three borders (anterior, posterior and interosseous) and three surfaces (anterior, posterior and lateral) (Fig. 11.22).

The ***interosseous or medial border*** is the prominent sharp ridge that extends from below the radial tuberosity to the medial side of the lower end of the bone. Near the lower end, this border forms the posterior margin of a small triangular area.

The ***anterior border*** begins at the anterior aspect of the radial tuberosity and runs downwards and laterally across the anterior aspect of the shaft. This part of the anterior border is called the ***anterior oblique line***. It then runs downwards and forms the lateral boundary of the smooth anterior surface of the lower part of the shaft. The upper part of the ***posterior border*** runs downwards and laterally from the posterior part of the tuberosity. The lower part of the posterior border runs downwards along the middle of the posterior aspect of the shaft to the lower end.

The ***anterior surface*** lies between the interosseous and the anterior borders; the ***posterior surface*** between the interosseous and the posterior borders and the ***lateral surface*** between the anterior and the posterior borders. The anterior surface is smooth and continues inferiorly as the anterior surface of the lower end. The posterior surface is comparatively flatter and merges with the lateral surface in the inferior aspect. The lateral surface is indistinct

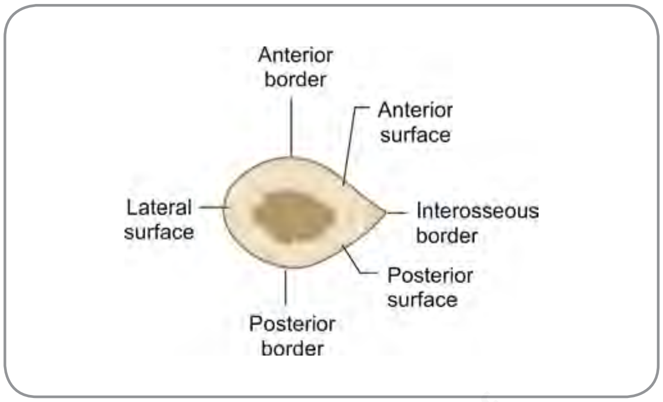


Fig. 11.22: Transverse section across the middle of the shaft of the radius to show its borders and surfaces

inferiorly but expands into a wide triangular area in the upper part of the bone as it extends onto the anterior and posterior aspects. It also shows a rough area near the middle and most convex part of the shaft.

Lower End

The lower end of the radius has anterior, lateral and posterior surfaces which are continuous with the corresponding surfaces of the shaft. In addition, it has a medial surface and an inferior surface. The lateral surface is prolonged downwards as a projection called the ***styloid process***. The medial aspect of the lower end has an articular area called the ***ulnar notch*** which articulates with the lower end of the ulna to form the ***inferior radioulnar joint***. Just above the notch, there is a triangular area bounded posteriorly by the interosseous border (Fig. 11.23).

The posterior aspect of the lower end is marked by a number of vertical grooves separated by ridges. The most prominent ridge, called the ***dorsal tubercle*** (or Lister s tubercle or dorsal radial tubercle), is placed roughly midway between the medial and lateral aspects of the lower end. Immediately medial to the tubercle is a narrow

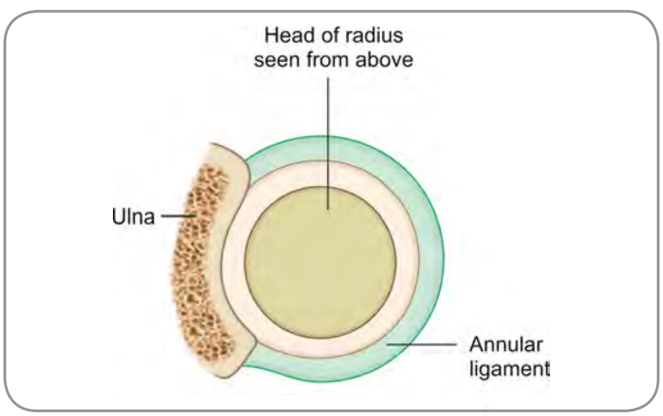
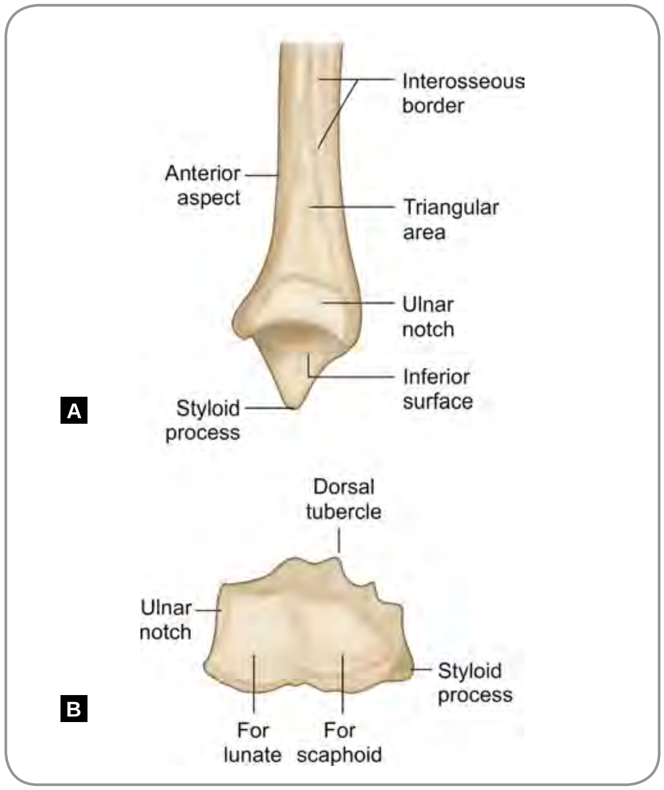


Fig. 11.23: Scheme to show the relationship of the head of the radius to the ulna and to the annula ligament



Figs 11.24A and B: Lower end of the right radius seen **A.** From the medial side **B.** From below

oblique groove, and still more medially, is a wide shallow groove. The area lateral to the dorsal tubercle also shows two grooves separated by a ridge.

The inferior surface of the lower end is concave and articular. It extends onto the medial surface of the styloid process and takes part in the formation of the wrist joint. It is subdivided into a medial quadrangular area that articulates with the lunate bone and a lateral triangular area that articulates with the scaphoid bone (Fig. 11.24).

Attachments of Various Structures (Fig. 11.25)

Muscular Insertions

- The ***biceps brachii*** is inserted into the rough posterior part of the radial tuberosity.
- The ***supinator*** is inserted into the upper part of the lateral surface. The area of insertion extends onto the ***anterior*** and ***posterior*** aspects of the shaft.
- The ***pronator teres*** is inserted into the rough area on the middle of the ***lateral*** surface at the point of maximum convexity of the shaft.
- The ***brachioradialis*** is inserted into the lowest part of the lateral surface just above the styloid process.
- The ***pronator quadratus*** is inserted into the lower part of the anterior surface and into the triangular area on the medial side of the lower end.

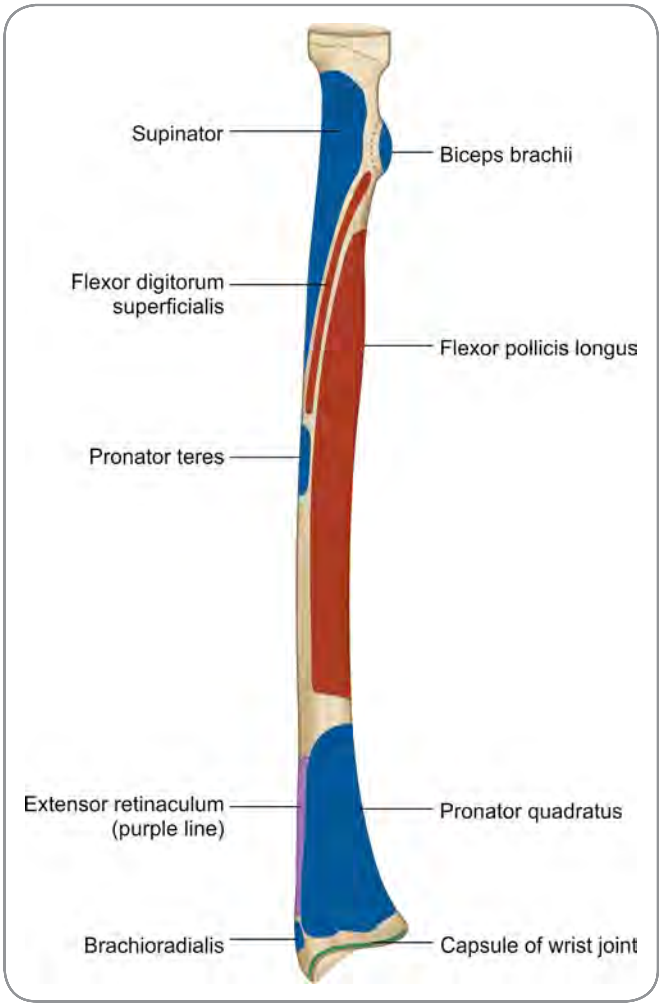


Fig. 11.25: Right radius showing attachments-seen from the front

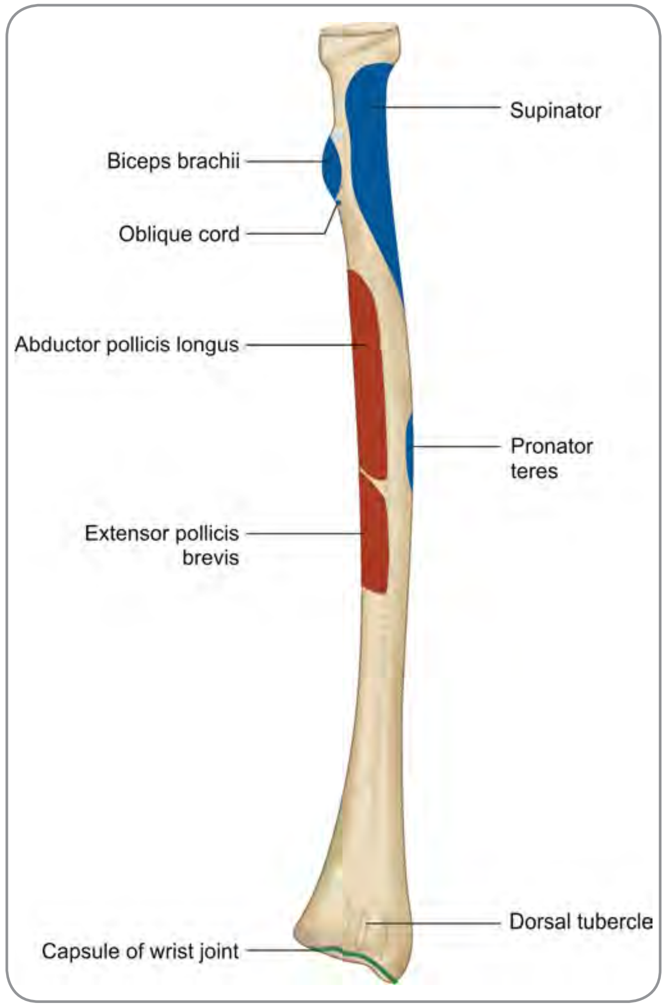


Fig 11.26: Right radius showing attachments-seen from behind

Muscular Origins (Fig. 11.26)

- The ***flexor digitorum superficialis*** (radial head) arises from the upper part of the anterior border (oblique line)
- The ***flexor pollicis longus*** arises from the upper two-thirds of the anterior surface
- The ***abductor pollicis longus*** arises from the upper part of the posterior surface
- The ***extensor pollicis brevis*** arises from a small area on the posterior surface below the area for the ***abductor pollicis longus.***

Attachments of Other Structures

The radial dorsal tubercle receives a slip from the extensor retinaculum and is grooved medially by the tendon of extensor pollicis longus. The groove lateral to the tubercle contains the tendons of extensor ***carpi radialis longus*** laterally and ***extensor carpi radialis brevis*** medially. Medially the dorsal surface is grooved by the tendons of extensor indicis and posterior interosseous nerve (Fig. 11.27).

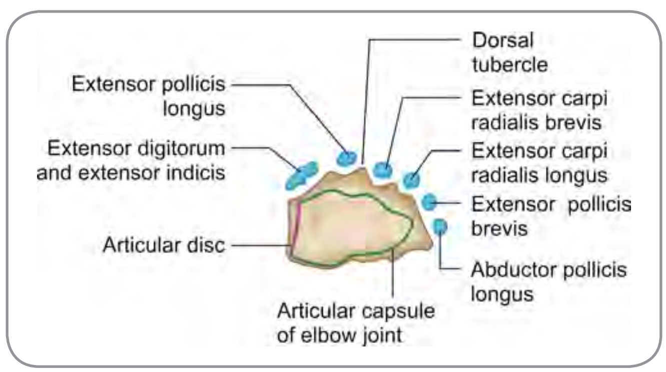


Fig. 11.27: Lower end of right radius seen from below-the related tendons are shown

Ossification

A primary centre appears in the shaft during the 8th week of foetal life. A secondary centre appears in the lower end in the first or second year and joins the shaft around 18 years of age. Another secondary centre appears in the

Clinical Correlation

- The growing end is the lower end. The nutrient artery which is directed to the elbow is a branch of the anterior interosseous artery.
- **Fractures of the Radius (Fig. 11.28)**

Since radius is the weight-bearing bone, it is more prone to fractures and injuries.

The radius may be fractured through the middle of its shaft (either alone or along with the shaft of the ulna). It may also be fractured either through the upper end (or head) or through the lower end. Fracture of the lower end is called ***Colles' fracture***. This fracture is very common in older persons specially women. Usually, the lower fragment is displaced backwards and laterally resulting in what has been called a ***'dinner-fork'*** deformity. The radial styloid process which normally lies distal to the ulnar styloid process becomes proximal. Complications of this fracture include injury to or compression of the median nerve, rupture of the tendon of the extensor pollicis longus and subluxation of the inferior radioulnar joint. Occasionally, fracture of the lower end of the radius is associated with forward displacement (as against backward displacement in Colles' fracture). This is called ***Smith's fracture*** or ***Barton's fracture*** or reversed Colles' fracture.

head of the radius during the 4th or 5th year and fuses with the shaft around the 16th year. Occasionally, the radial tuberosity may ossify from a separate centre which appears around puberty.

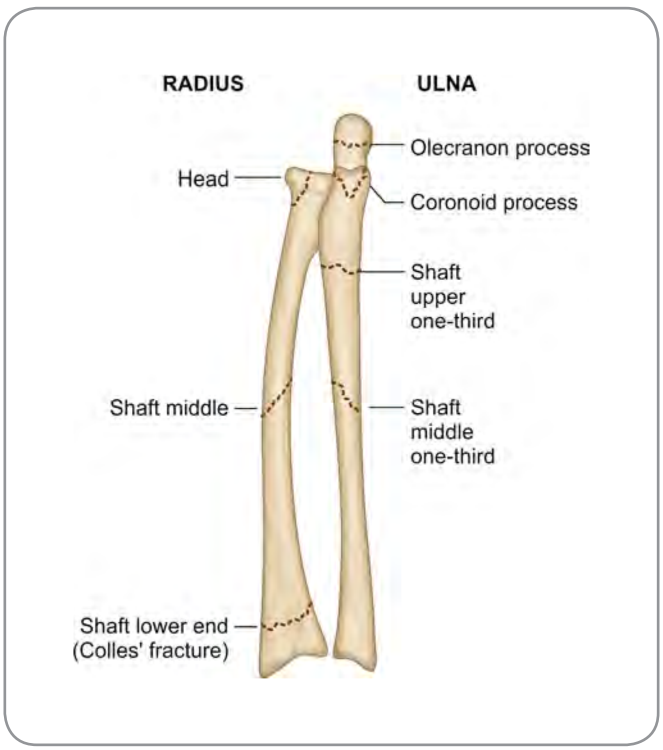


Fig. 11.28: Fractures of radius and u na

ULNA

Another name: Elbow bone

The ulna (Latin.ulne=elbow, Greek.olene=elbow) is the medial of the two forearm bones and is longer than the lateral radius. It extends from the elbow to the wrist and also overlaps the humerus. It is subcutaneous and can be felt in its whole length at the back of the forearm. It is a long bone with a shaft, the upper and the lower ends. It is important to note that the head of the bone is in the lower end.

Side Determination

- The upper end is large and irregular, while the lower end is small.
- The anterior aspect of the upper end has a large ***trochlear notch.***
- The lateral margin of the shaft is sharp and thin, while the medial side is rounded.

From the above-mentioned facts, the side of a given ulna can be determined (Figs 11.29 and 11.30).

Upper End

The ***upper end*** of the ulna is large and consists of two prominent projections called the ***olecranon process*** and the ***coronoid process***. These two processes enclose a concavity, thereby giving the bone a spanner-like appearance When seen from behind, the olecranon process appears to be a direct upward continuation of the shaft and forms the uppermost part of the ulna. It can be easily felt in the living subject and forms what is called the 'point of elbow'. The coronoid process projects forwards from the anterior aspect of the ulna just below the olecranon. The concavity enclosed is the ***trochlear notch*** and is formed by the anterior aspect of the olecranon process and the superior aspect of the coronoid process. It takes part in the formation of the elbow joint and articulates with the trochlea of the humerus. The upper and lower parts of the notch may be partially separated from each other by a non-articular area. The trochlear notch is also divisible into medial and lateral areas corresponding to the medial and lateral flanges of the trochlea of the humerus.

In addition to its anterior surface, which forms the upper part of the trochlear notch, ***the olecranon process*** (Greek.olene=ulna, kranion=head) has superior, posterior, medial and lateral surfaces. When viewed from the lateral side, the uppermost part of the olecranon is seen projecting forwards beyond the rest of the process. The superior surface tapers in front. The posterior surface is smooth and subcutaneous and extends to the shaft as a triangle. The medial and lateral surfaces are rough.

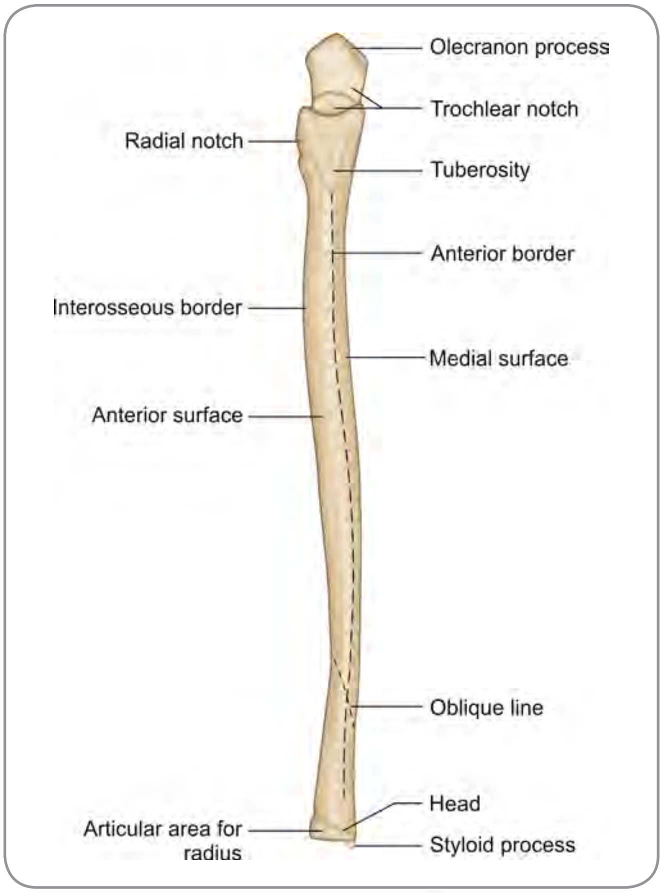


Fig. 11.29: Right ulna-seen from the front

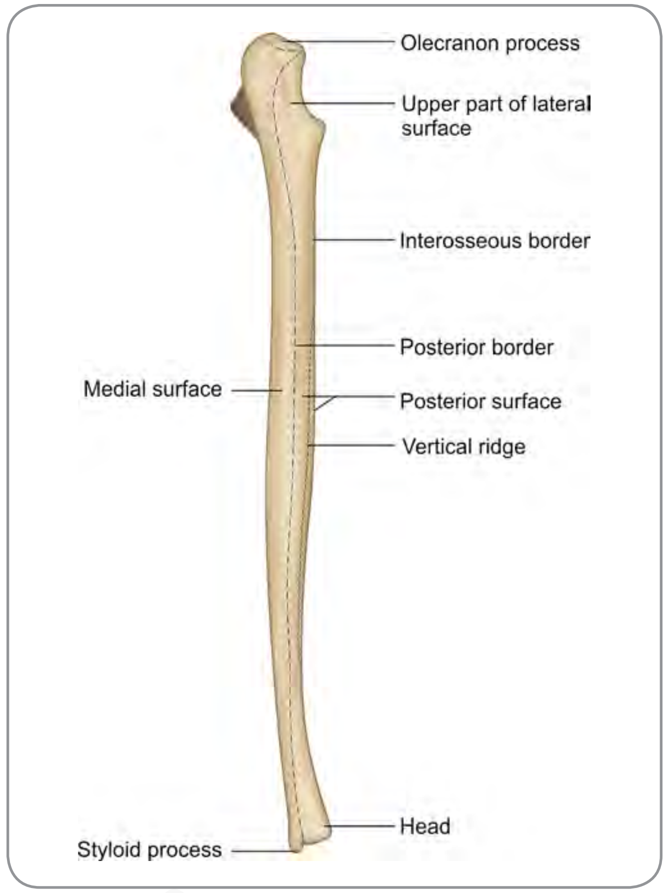


Fig 11.30: Right ulna-seen from behind

The ***coronoid process*** (Greek korone=crow, also Greek. coronae=garland or crown, crow-beak appearance or crown-like appearance) has an upper surface that forms the lower part of the trochlear notch. In addition, it has anterior, medial and lateral surfaces. The anterior surface is triangular. Its lower part shows a rough projection called the ***tuberosity*** of the ulna. The medial margin of the anterior surface is sharp and shows a small tubercle at its upper end.

The upper part of the lateral surface of the coronoid process shows a concave articular facet called the ***radial notch***. The radial notch articulates with the head of the radius forming the superior radioulnar joint. A depression is seen just below the radial notch. The posterior border of this depression is formed by a ridge called the ***supinator crest***.

Shaft

The shaft of the ulna is predominantly triangular in section and tapers to a slender rounded part. However it again widens in the lower portion. The shaft has a sharp lateral or interosseous border, and less prominent anterior and posterior borders. It has anterior, posterior and medial surfaces.

The prominent lateral edge of the shaft is the ***interosseous border***. In the upper part, it is continuous with the supinator crest; in the middle, it forms a prominent ridge on the lateral aspect of the shaft and in the lower part, it is indistinct and ends on the lateral side of the head. The ***anterior border*** begins at the tuberosity of the ulna and runs downwards. Near its lower end, it curves backwards to end in front of the styloid process The ***posterior border*** begins at the apex of the triangular area on the posterior aspect of the olecranon process and ends at the styloid process (Figs 11.31 and 11.32).

The ***anterior surface*** lies between the interosseous and anterior borders. Its lower part shows an oblique ridge that runs downwards and medially from the interosseous border. The ***medial surface*** lies between the anterior and posterior borders. The ***posterior surface*** is bounded by the interosseous and posterior borders. It is marked by two lines that divide it into three areas. The upper end of

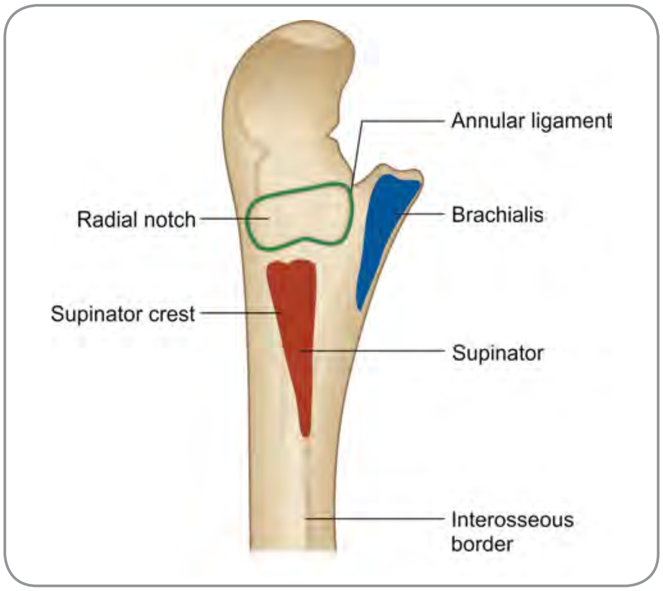


Fig. 11.31: Upper end of right ulna showing attachments-seen from the lateral side

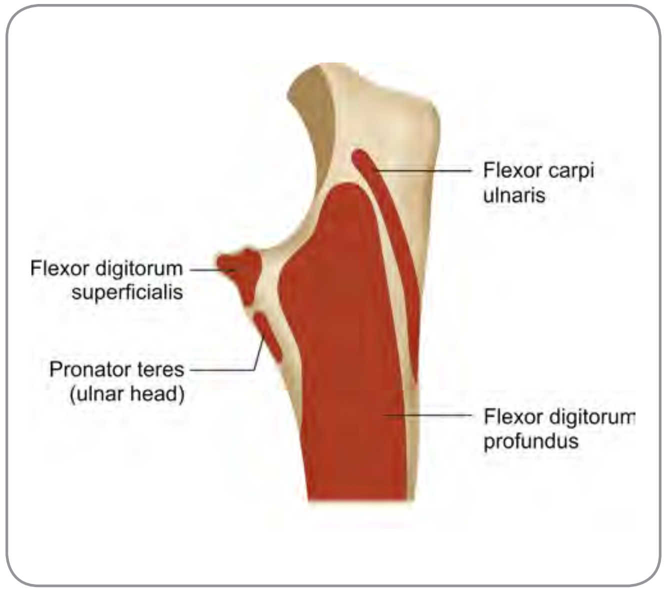


Fig. 11.32: Upper end of right ulna showing attachments-seen from the medial side

these lines runs obliquely downwards and medially across the upper part of the surface. It starts at the posterior end of the radial notch and terminates by joining the posterior border. The part of the posterior surface above the oblique line is triangular. The part below the oblique line is subdivided into medial and lateral parts by a vertical ridge.

Lower End

The lower end of the ulna consists of a disc-like ***head*** and a ***styloid process***. The head is rounded and has a circular inferior surface. This surface is separated from the cavity of the wrist joint by an articular disc which comes in apposition with the triquetral bone. Hence the ulna bone does not take part directly in the formation of the wrist joint. The head has another convex articular surface on its lateral side. This surface articulates with the ulnar notch of the radius to form the inferior radioulnar joint. The styloid process (Latin.stylus=pen or stick) is a small downward projection that lies on the posteromedial aspect of the head. Between the styloid process and the head, the posterior aspect is marked by a vertical groove. It is of importance to note that the tip of the styloid process of the ulna lies at a higher level than the styloid process of the radius when articulated.

Attachments of Various Structures

Muscular Insertions

- The ***brachialis*** is inserted into the anterior surface of the coronoid process including the tuberosity.
- The ***triceps*** is inserted into the posterior part of the superior surface of the olecranon process.

Muscular Origins

- The ***flexor digitorum profundus*** arises from the upper three-fourths of the anterior and medial surfaces. The muscle also takes origin from the posterior border through an aponeurosis common to it, the flexor carpi ulnaris and the extensor carpi ulnaris (Fig. 11.33).
- The ***supinator*** arises from the supinator crest and from the triangular area in front of it.
- The ***flexor pollicis longus*** (occasional ulnar head) arises from the lateral border of the coronoid process.
- The ***flexor digitorum superficialis*** (ulnar head) arises from the tubercle at the upper end of the medial margin of the coronoid process.
- The ***pronator teres*** (ulnar head) arises from the medial margin of the coronoid process.
- The ***pronator quadratus*** arises from the oblique ridge on the lower part of the anterior surface of the shaft
- The ***flexor carpi ulnaris*** (ulnar head) arises from the medial side of the olecranon process and from the upper two-thirds of the posterior border through an aponeurosis common to it, the extensor carpi ulnaris and the flexor digitorum profundus.
- The ***extensor carpi ulnaris*** (ulnar head) arises from the posterior border by an aponeurosis common to it, the flexor carpi ulnaris and the flexor digitorum profundus.
- The posterior surface of the ulna is divided into medial and lateral parts by a vertical ridge. The lateral part lies between the vertical ridge and the interosseous border This part of the posterior surface may be divided into four parts:

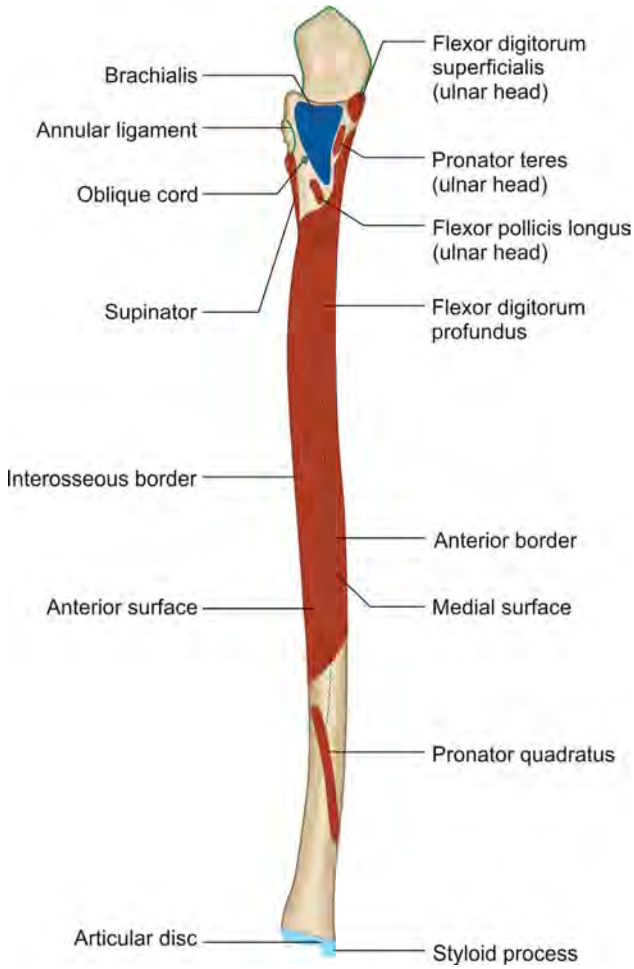


Fig. 11.33: Right ulna showing attachments-seen from the front

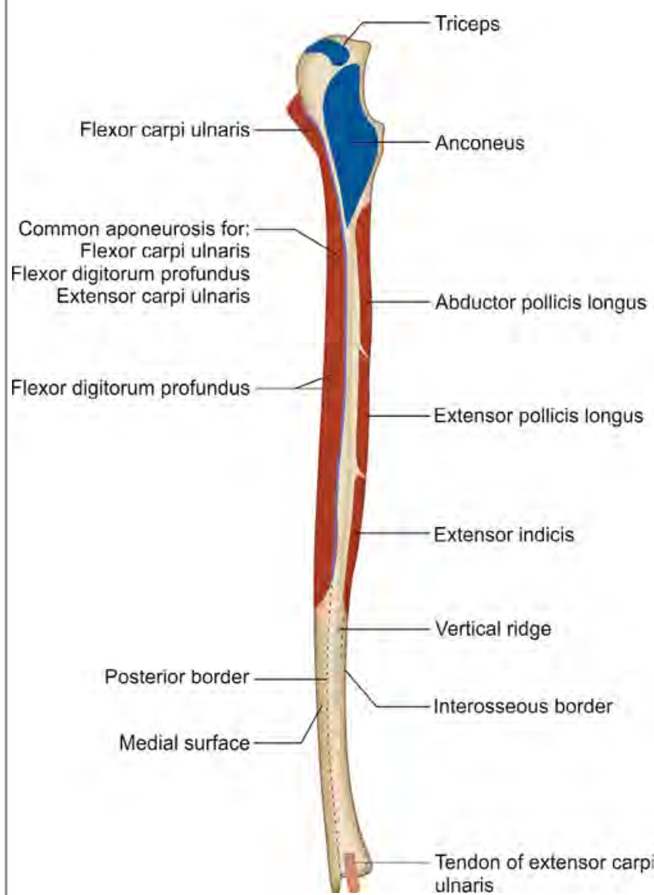


Fig. 11.34: Right ulna showing attachments-seen from behind

- The uppermost part gives origin to the ***abductor pollicis longus***;
- The next part gives origin to the ***extensor pollicis longus***;
- The lower part gives origin to the ***extensor indicis***;
- The lowest part is devoid of attachments (Fig. 11.34).

Ossification

A primary centre appears in the shaft in the 8th foetal week and forms the greater part of the ulna. A centre for the lower end appears around the 5th or 6th year and joins the shaft by the 18th year. The greater part of the olecranon is ossified by extension from the primary centre. The proximal part of the process is ossified from two centres that appear around the 10th year and join the shaft around the 15th year.

SKELETON OF HAND

The skeleton of the hand consists of the bones of the wrist, palm and fingers. The components, therefore, are the bones of the carpus, metacarpus and the phalanges (Fig. 11.35).

The term ***carpus*** (Greek.karpos=wrist) indicates a group of eight small bones in the region of the wrist. The skeleton of the palm is made up of five metacarpal bones. These are miniature 'long' bones. The skeleton of the fingers is made up of the phalanges. There are three phalanges (proximal, middle and distal) in each finger except the thumb which has only two phalanges (proximal and distal).

Carpal Bones

The bones of the carpus, usually referred to as the carpal bones, are arranged in two rows, namely proximal and

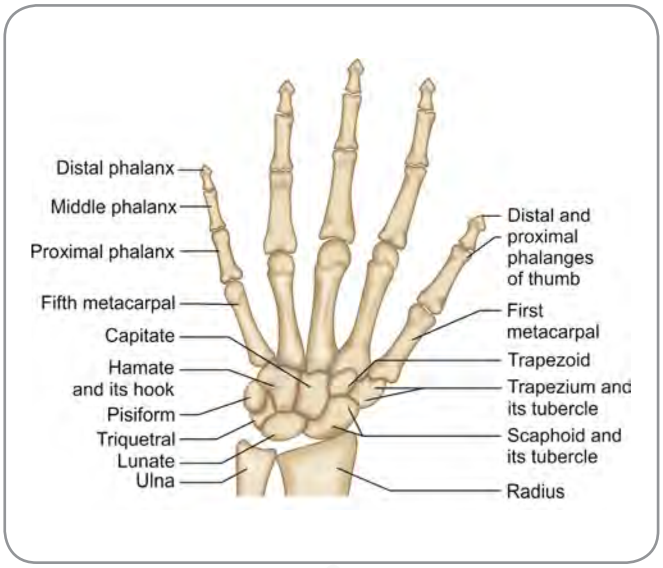


Fig. 11.35: Skeleton of the hand-seen from the palmar aspect

distal (Fig. 11.36). The proximal row is made up of the scaphoid, lunate, triquetral and pisiform bones from lateral to medial side. The distal row is made up of the trapezium trapezoid, capitate and hamate bones from lateral to medial side (Fig. 11.37). Except the pisiform bone, all other carpal bones of the proximal row take part in the formation of the wrist joint. The distal row of carpal bones articulate with the metacarpal bones. Each carpal bone also articulates with its neighbouring carpal bones to form the intercarpal joints.

The carpal bones are so bound together that they form a single compact mass which has a pronounced anterior concavity called the ***carpal sulcus***. This sulcus is converted into a carpal tunnel by the flexor retinaculum of the hand.

Scaphoid Bone

Other names os scaphoideum, navicular of the hand

The scaphoid bone can be distinguished because of its distinctive ***boat-like*** shape as its name suggests (Greek. scaphe=boat). The proximal part of the bone is covered by a large, convex, articular surface of the radius. Distally and laterally, the palmar surface of the bone bears a projection called the ***tubercle***. The medial surface of the scaphoid articulates with the lunate bone (proximally) and with the capitates (distally). The distal surface of the scaphoid articulates with the trapezium (laterally) and with the trapezoid bone (medially).

Lunate Bone

Other names: Os lunatum, Os intermedium, semilunar bone.

The lunate bone can be distinguished because it is shaped like a ***lunar crescent*** (Latin.luna=moon). Proximally, the bone has a convex articular facet that takes part in the formation of the wrist joint. The bone articulates laterally with the scaphoid; medially with the triquetral. Distally, it articulates with the capitate. Between the areas for the capitate and for the triquetral, the lunate may articulate with the hamate bone.

Triquetral Bone

Other names: Triquetrum, Os triangulare, cubital bone, pyramidal bone, three-cornered bone.

The triquetral bone (Latin.tri=three, quetrus=cornered) can be distinguished from other carpal bones by the fact that it is a small roughly cuboidal bone. It has palmar, dorsal, proximal, distal, medial and lateral surfaces. The distal part of its palmar surface articulates with the pisiform bone. The medial surface is directed as much proximally as

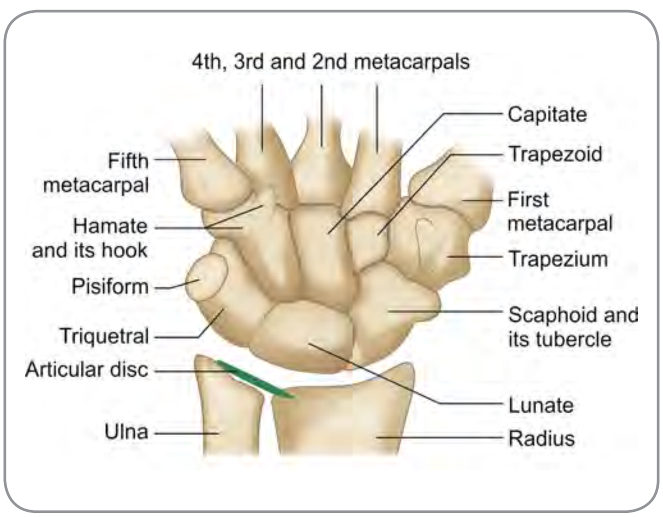


Fig. 11.36: Right carpus seen f om the front

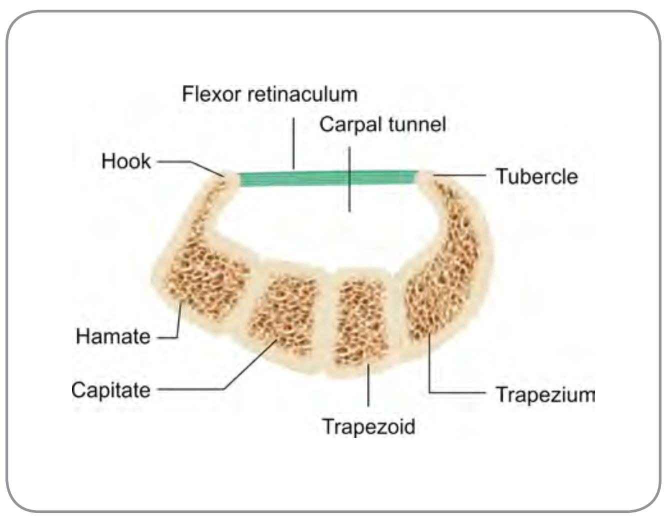


Fig. 11.37: Schematic section across the distal row of carpal bones

medially. It bears a slightly convex surface that takes part in the formation of the wrist joint and comes into contact with the articular disc of the infer or radioulnar joint. Its lateral surface is directed distally and articulates with the hamate bone. The proximal surface is directed laterally and articulates with the lunate bone.

Pisiform Bone

Other name: Lentiform bone.

This bone is easily distinguished as it is shaped like a pea (Latin.pisum=pea, formis=appearance). Its dorsal aspect bears a single facet for articulation with the triquetral bone. It is difficult to determine the side of this bone. It is usually considered to be a sesamoid bone developed in the tendon of flexor carpi ulnaris.

Trapezium

Other names: Os multangulum majus, greater multangular bone.

This bone (Greek trapezoin=table, meaning four-sided) can be distinguished because it bears a thick prominent ***ridge*** on its palmar aspect, which is called the ***tubercle***. The trapezium articulates proximally and medially with the scaphoid. Distally and laterally, it articulates with the first metacarpal bone. Distally and medially, it articulates with the base of the second metacarpal bone. Medially, it articulates with the trapezoid bone.

Trapezoid Bone

Other names: Os multangulum minus, lesser multangular bone.

This bone (trapezoid=like a trapezium) can be distinguished from other carpal bones because of its small size and its irregular shape resembling that of a shoe. The trapezoid articulates distally with the base of the second metacarpal bone. Laterally, it articulates with the trapezium. Medially, it articulates with the capitate bone. Proximally, it articulates with the scaphoid bone.

Capitate Bone

Other names: Os capitatum, os magnum.

The capitate bone (Latin.caput=head) is easily recognised as it is the largest carpal bone, and bears a rounded ***head*** at one end. The capitate lies right in the middle of the carpus. Proximally, it articulates with the lunate bone the rounded head fitting into a socket formed by the lunate and scaphoid bones. Distally, the capitate bone articulates mainly with the third metacarpal bone, but it also articulates with the second and fourth metacarpal bones. Laterally, it articulates with the scaphoid (proximally) and the trapezoid (distally). Medially, it articulates with the hamate bone.

Hamate Bone

Other names Os hamatum, hooked bone, unciform bone.

The hamate (Latin.hamus=hook, Latin.uncinatum= hooklike) is easy to recognise as it has a prominent ***hook-like process*** attached to the distal and medial parts of its palmar aspect. When viewed from the palmar aspect, the hamate is triangular in shape, the apex of the triangle being directed proximally. Proximally, the apex of the bone may articulate with the lunate bone. Distally, the hamate articulates with the fourth and fifth metacarpal bones. Medially and proximally, the hamate articulates with the triquetral bone. Laterally, the hamate bone articulates with the capitate bone

Carpal Tunnel (Fig. 11.37)

The carpal bones are so arranged that the dorsal, medial and lateral surfaces of the carpus form one convex surface. On the other hand, the palmar surface is deeply concave with overhanging medial and lateral projections. This concavity called the ***carpal sulcus*** is converted into the carpal tunnel by a band of fascia called the flexor retinaculum. The flexor retinaculum is attached medially to the pisiform bone and the hook of the hamate; and laterally to the tubercle of the scaphoid and tubercle of the trapezium.

METACARPAL BONES

The hand has five metacarpal bones (Greek.meta=beyond, metacarpal=beyond carpal) (Fig. 11.38). They are numbered from lateral to medial side so that the bone related to the thumb is the first metacarpal, and that related to the little finger is the fifth. Each metacarpal is a miniature long bone having a shaft, a distal end and a proximal end. The distal end forms a rounded head. It bears a large convex articular surface for

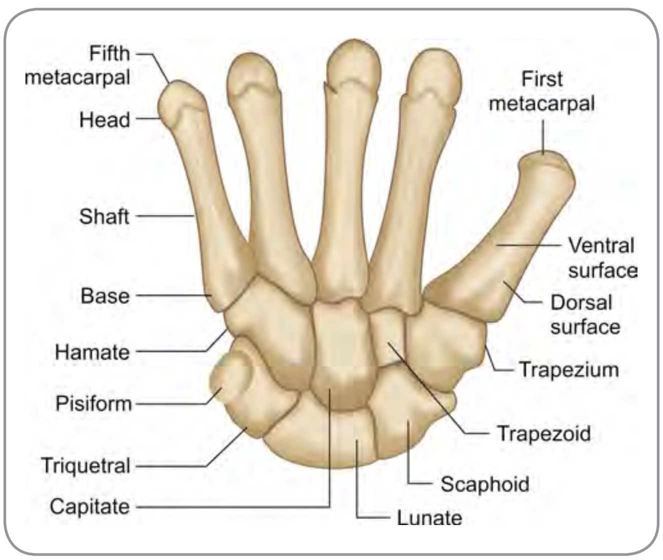


Fig. 11.38 Carpal and metacarpal bones-seen from front

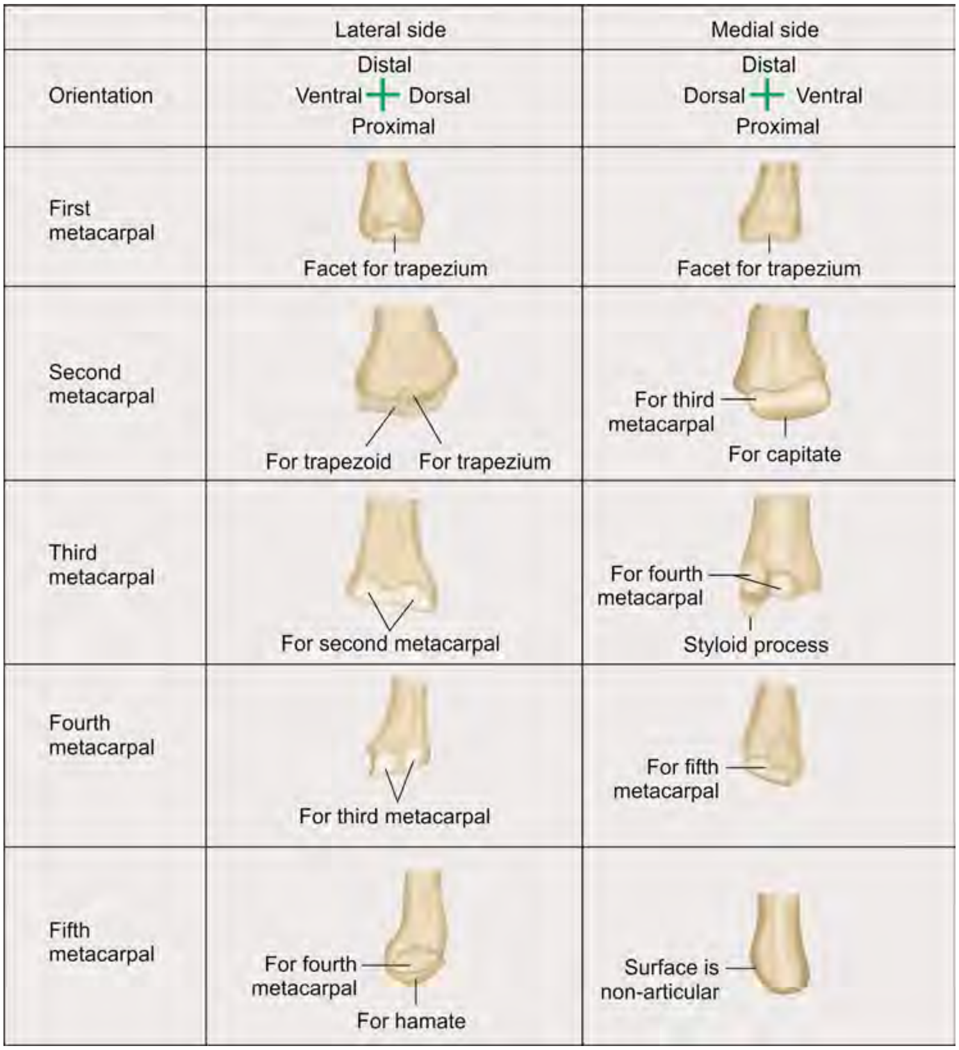


Fig. 11.39: Facets seen on bases of metacarpal bones (right)

articulation with the proximal phalanx of the corresponding digit. The shaft is triangular in cross-section and has medial, lateral and dorsal surfaces. The bases (or proximal ends) of the metacarpal bones are irregular in shape. They articulate with the distal row of carpal bones. The bases of the second and third, third and fourth, and fourth and fifth metacarpal bones also articulate with each other (Fig. 11.39).

The base of each of the metacarpal bones has certain characteristics that enable us to distinguish them from each other (Fig. 11.39).

PHALANGES OF HAND

Other name: Ossa digitorum manus

The arrangement of the phalanges of the hand and foot is similar. Each digit of the hand, except the thumb, has three phalanges: proximal, middle and distal (Fig. 11.40). The thumb has only two phalanges: proximal and distal. Each phalanx has a distal end or head, a proximal end or base, and an intervening shaft or body which tapers distally. The bases of the proximal phalanges carry concave, oval facets adapted to articulate with the metacarpal heads.

Ossification of the Bones of Hand

Carpal Bones

All the carpal bones are cartilaginous at birth. Each carpal bone has one centre which appears before birth. The ossification of the carpal bones starts after birth, which is as follows:

Capitate : 2nd month
Hamate : 3rd month (sometimes the capitate and hamate may start ossifying before birth)

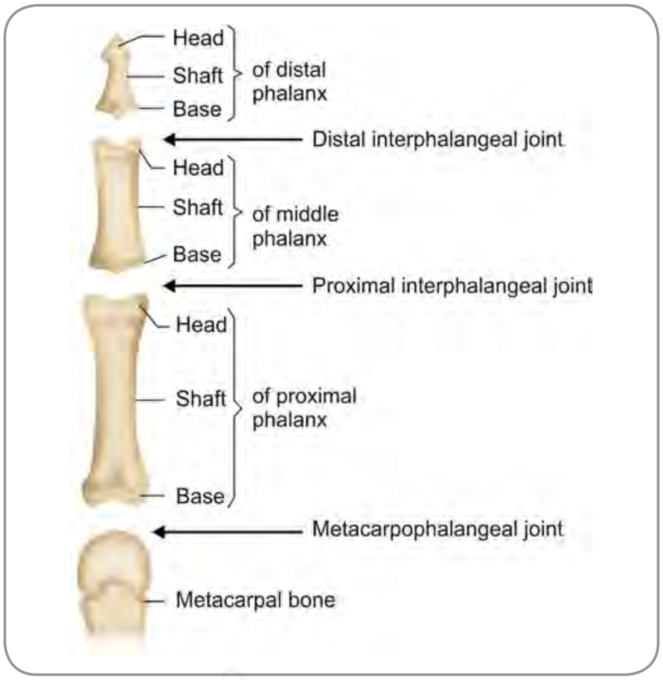


Fig. 11.40: The phalanges of a typical digit of the hand

Triquetral	:	3rd year
Lunate	:	4th year
Scaphoid	:	4th to 5th year
Trapezium	:	4th to 5th year
Trapezoid	:	4th to 5th year
Pisiform	:	About 10th year

Metacarpals

Each metacarpal has a primary centre for the shaft that appears in the 9th foetal week. The first metacarpal has a secondary centre for the base that appears in the 2nd or 3rd year and unites with the shaft at about 16 years. The other metacarpal bones have secondary centres in the heads and not in the bases. These appear at about two years of age and unite with the shaft between 16 and 18 years of age

Phalanges

Each phalanx has a primary centre for the shaft and a secondary centre for its proximal end. The primary centre appears first in the distal phalanges (about the 8th week); next in the proximal phalanges (about the 10th week); and last in the middle phalanges (about the 12th foetal week). The secondary centres appear first in the proximal phalanges (2nd year) and later in the middle and distal phalanges (3rd or 4th year). They unite with the shafts between 16 and 18 years of age.

Clinical Correlation

Fractures of Bones of the Hand

- The scaphoid bone is the most commonly fractured carpal bone. It often results from a fall on the palm when the hand is abducted, the fracture occurring across the narrow part called waist of the scaphoid. Pain occurs primarily on the lateral side of the wrist. Clinical examination shows tenderness over the anatomical snuff box. Owing to the poor blood supply to the proximal part of the scaphoid, union of the fractured parts may take at least 3 months. Avascular necrosis of the proximal fragment of the scaphoid (pathological death of bone resulting from inadequate blood supply) may occur and produce degenerative joint disease of the wrist.
- Fractures of other carpal bones are rare. Fracture or dislocation of lunate bone can cause carpal tunnel syndrome.
- The first metacarpal bone is usually fractured near its base. The fracture often involves the carpometacarpal joint.
- Other metacarpal bones and phalanges are fractured by direct injury:
  - A metacarpal bone may be f actured through the base, the shaft or the neck (i.e , just proximal to the head).
  - Phalanges may be fractured through the shaft or through either end

Multiple Choice Questions

1. Conoid tubercle is found near the
   a. Anterior border of the lateral third of the clavicle
   b. Posterior border of the lateral third of the clavicle
   c. Posterior border of the medial third of the clavicle
   d. Anterior border of the medial third of the clavicle

2. The strengthening bar of scapula is seen adjoining its:
   a. Axillary border
   b. Vertebral border
   c. Superior border
   d. Suprascapular notch

3. The functional joint where movements occur between the scapula and the thoracic wall is:
   a. Scapula humeral joint
   b. Scapulothoracic joint
   c. Thoracohumeral joint
   d. Scapuloclavicular joint

4. Dinner fork deformity results when:
   a. Fractured distal segment of radius is displaced backwards and laterally
   b. Fractured distal segment of radius is displaced forwards and laterally
   c. Fractured proximal segment of radius is displaced backwards and laterally
   d. Fractured distal segment of radius is displaced further distally

5. The carpal bone of the proximal row that does not take part in wrist joint is:
   a. Trapezius
   b. Trapezoid
   c. Capitate
   d. Pisiform

ANSWERS

1. b **2.** a **3.** b **4.** a **5.** d

Clinical Problem-solving

Case Study 1: One of your friends had a fall and sustained a fracture of his right humerus. As you visit him in the hospital, you are informed that he has a fracture in the upper part of the bone.

- By common occurrence, where do you expect the fracture to have occurred? Substantiate your answer.
- Do you think any nerve would have been damaged? If so, which nerve?
- What are the other nerves which may be involved if fracture had occurred in other parts of the bone?

Case Study 2: A 45-year-old woman fell on an outstretched upper limb with the palm bearing the impact. Her hand was abducted at the time of the impact. She complained of intense pain in the lateral aspect of her wrist.

- Which of the carpal bones do you expect to have had a fracture?
- What is the consequence of such a fracture?
- If a complication occurs, what other structure/part do you think would be affected?

(For solutions see Appendix).

Chapter **12**

Pectoral Region and Breast

Frequently Asked Questions

- Write notes on (a) Clavipectoral fascia, (b) Pectoralis major, (c) Pectoralis mino (d) Subclavius.
- Discuss the pectoralis major in detail.
- Describe the mammary gland in detail.
- Write notes on (a) Lymphatic drainage of mammary gland, (b) Development and congenital anomalies of mammary gland (c) Age changes in the mammary gland.
- Discuss the microstructural features of the mammary gland.

PECTORAL REGION

The pectoral region (Latin.pectus=chest) lies on the front of the thorax. In the mature female, the breasts lie over this region.

SUPERFICIAL STRUCTURES OF PECTORAL REGION

The superficial structures of the pectoral region includes the cutaneous nerves and the fasciae of the region. The cutaneous nerves deserve a special mention; they are derived from the C3, C4 spinal and T2, T3 spinal segments. This fact draws importance because the muscles of the upper limb receive innervation through the brachial plexus from C5 to T1 spinal segments. Thus the cutaneous innervation of the pectoral region involves additional spinal segments (Fig. 12.1).

Cutaneous Nerves of the Pectoral Region

The skin of the pectoral region is supplied by the supraclavicular nerves and the cutaneous branches of the intercostal nerves.

The supraclavicular nerves (C3, 4) arise in the neck from the cervical plexus. The nerve trunk originates deep to the sternocleidomastoid muscle, runs downwards and backwards deep to it and appears at ts posterior border. Here, the trunk divides into three branches called the medial, intermediate and lateral supraclavicular nerves. These branches descend over the posterior triangle of the neck, pierce the deep fascia a little above the clavicle and then run downwards across it to reach the pectoral region.

- The ***medial supraclavicular nerve*** supplies the skin of the upper and medial part of the thorax. A branch from the nerve supplies the sternoclavicular joint.
- The ***intermediate supraclavicular nerve*** supplies the skin over the upper part of the pectoralis major The area of supply of the medial and intermediate supraclavicular nerves extends up to the level of the second rib
- The ***lateral supraclavicular nerve*** supplies the skin over the shoulder and the acromio-clavicular joint.

The intercostal nerves which are the ventral primary rami of the thoracic spinal nerves give two cutaneous branches each, namely the anterior cutaneous nerve and the lateral cutaneous nerve. The skin below the level of

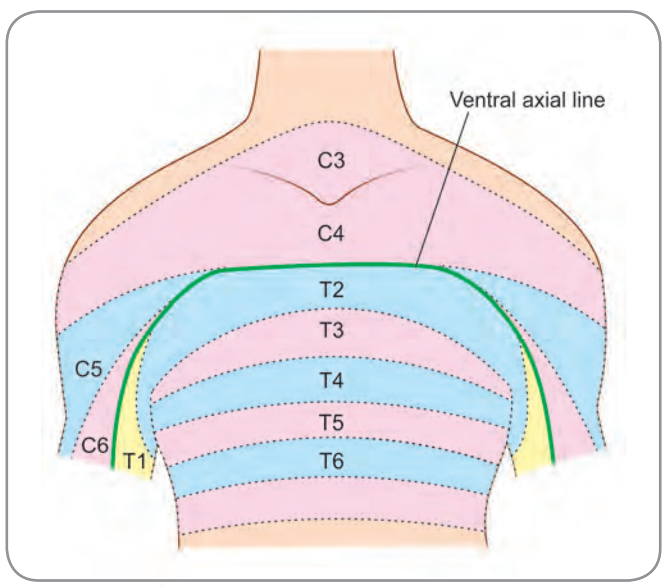


Fig. 12 1: Cutaneous innervation of pectoral region

Dissection

With the cadaver in the supine position, make necessary incisions to open up the superficial areas of the anterior chest wall. The skin is very thin here and care must be taken not to cut deep. The required incisions are:

- A midline incision from jugular notch to xiphisternal junction;
- An incision from jugular notch to acromion along the clavicle (try to preserve the platysma and supraclavicular nerves while making this);
- A transverse incision from the xiphisternal junction to the lateral aspect of the trunk;
- An incision that runs upwards and laterally from the xiphisternal junction; this will pass around the nipple and continue to the anterior axillary fold and then curve down to the medial aspect of the arm.

The skin and superficial fascia should be reflected laterally using blunt dissection. Leave the nipple intact.

Observe the thin strands of fibrous tissue passing from the skin to the deep fascia in the egion of the breast. Similarly, observe the thin twigs of the supraclavicular nerves as you reflect the skin along the clavicle and the lateral cutaneous branches of the intercostal nerves as you work in the area of the anterior axillary fold.

Dissection

Look out for the margins of pectoralis major and deltoid Clean the area of the deltopectoral groove and divide the deep fascia over the groove. The cephalic vein will be uncovered. A few lymph nodes may also be seen along the vein

It is preferable to dissect and study the breast region before any other related area is studied.

Development

The discontinuity (the gap between C4 and T2) in the dermatomes supplying the pectoral region is because of developmental reasons. During foetal development, the upper limb bud starts growing out of the trunk. As various muscular and other structures grow within the limb the ventral rami of spinal nerves C5,6,7,8 and T1 are drawn into the developing limb to supply it with both motor and sensory fibres As the limb grows, the areas of skin supplied from these segments get 'pulled away' into the limb. To fill the gap thus created, supraclavicular branches of C3 and 4 descend till the level of T2 supply and close the gap Therefore, there is no overlap between these areas as they are supplied by C4 and T2 and not by successive spinal nerves.

the sternal angle is supplied by the ***anterior cutaneous branches*** of the 2nd to 6th intercostal nerves More laterally, the supply is by the ***lateral cutaneous branches*** of the 3rd to 6th intercostal nerves.

Fasciae of the Pectoral Region

The superficial fascia over the chest is generally thin. However, it does contain a little amount of fat and in the females, the mammary gland is embedded in it. Fibres of the platysma muscle are also seen in the superficial fascia.

The deep fascia is also very thin. It is attached superiorly to the clavicle and medially to the sternum. It covers the pectoralis major muscle and is continuous inferiorly with the fascia of the anterior abdominal wall. Lateral to pectoralis major, it thickens to form the axillary fascia that forms the axillary floor. Since it covers the pectoralis major muscle, the deep fascia is very often called the pectoral fascia.

Clavipectoral Fascia

Deep to the pectoralis major muscle another fascia called the ***clavipectoral fascia*** is seen. It is so named as it is clearly seen between the clavicle and the superomedial border of pectoralis minor. At its upper end, the fascia splits into two layers to enclose the subclavius muscle and the two layers get attached to the inferior surface of the clavicle in front of and behind the subclavius. At the superomedial border of the pectoralis minor, it splits to enclose the muscle itself. At the inferolateral border of pectoralis minor, the two layers enclosing the muscle unite and the single layer continues to join the axillary fascia; as it joins the axillary fascia on the latter's superior aspect, it helps the axillary floor to be raised up into a dome. Thus the axillary fascia itself is raised into the hollow of the axillary pit and the extension of the clavipectoral fascia that lifts it up is called the ***suspensory ligament of the axilla*** (Fig. 12.2).

When traced medially from the subclavius, the clavipectoral fascia reaches the first two ribs and the first two intercostal spaces merging with the connective tissue of the region When traced laterally, it reaches the coracoid process and the coracoclavicular ligament Between the coracoid process and the first rib, it is thickened and therefore gets a separate name as the ***costocoracoid ligament***. The clavipectoral fascia is pierced by the cephalic vein, the thoracoacromial artery and some branches of lateral pectoral nerve. A few lymphatics of the

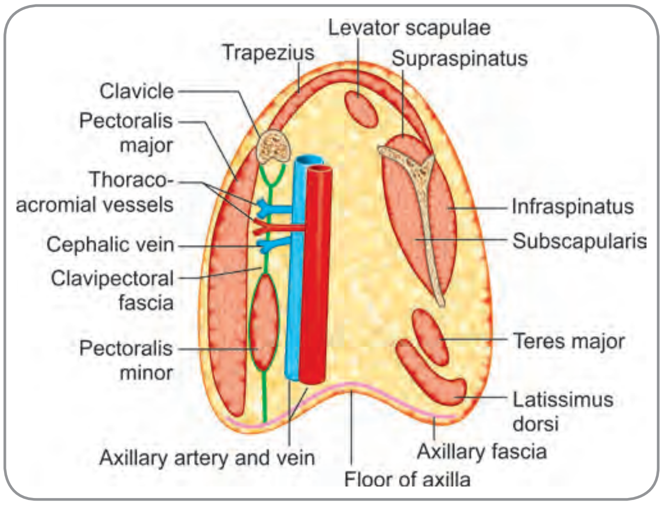


Fig. 12.2: Schematic sagittal section through the axila to show its anterior and posterior walls and the clavipectoral fascia

breast and the pectoral region may pierce through it to reach the apical axillary lymph nodes.

Added Information

- Dermatomes of the pectoral region: The areas of skin supplied by individual spinal nerves are called ***dermatomes***. As a rule, the arrangement of dermatomes is simple over the trunk, as successive horizontal strips of skin are supplied by each spinal nerve of the region (i.e., thoracic and lumbar nerves).The areas which are supplied by adjoining spinal nerves also overlap. However, the arrangement is unusual over the pectoral region—(a) The skin of the upper part of the pectoral region upto the level of the sternal angle is supplied by spinal segments C3 and C4; (b) The area just below the level of the sternal angle is supp ied by spinal segment T2.

contd...

Added Information *contd...*

- That part of the clavipectoral fascia between the pectoralis minor and the subclavius is being referred to as the costocoracoid membrane by many clinicians.

MUSCLES OF PECTORAL REGION

The muscles (Table 12.1) belonging to the pectoral region proper are:

- Pectoralis major
- Pectoralis minor
- Subclavius

Some portion of two other muscles are also seen in this region. These are:

- Platysma
- Serratus anterior

Table 12.1: Muscles of the pectoral region

Muscle	Origin	Insertion	Action	Nerve supply
Pectoralis major	By two heads: (Fig. 12.3) i. Clavicular head— – Medial half of anterior surface of clavicle ii. Sternocostal head— • Anterior surface of sternum • Medial parts of upper seven costal cartilages • Aponeurosis of external oblique muscle	• Lateral lip of intertubercular sulcus • The tendon of insertion is bilaminar. The anterior lamina receives the clavicular fibres and upper sternocostal fibres. The posterior lamina receives the lower sternocostal fibres.	• Adduction and medial rotation of arm • Flexion of arm (clavicular fibres with anterior fibres of deltoid) • Extension of flexed arm (against resistance) (sternocostal fibres with latissimus dorsi) • When the arm is raised above the head and fixed, the muscle can raise the thorax (as in climbing) (helped by latissimus dorsi) • Helps in forced inspiration (with the arms fixed).	• Lateral pectoral nerve (branch of lateral cord of brachial plexus) and medial pectoral nerve (branch of medial cord of brachial plexus) (C5, 6, 7, 8, T1).
Pectoralis minor	• 3rd , 4th and 5th ribs adjacent to the costal cartilages (Fig. 12.4) • Fascia adjoining 3rd and 4th intercostal spaces.	• Medial border and upper surface of coracoid process of scapula.	• Protraction of scapula (along with serratus anterior) • Depression of shoulder (along with levator scapulae and rhomboids) • Helps in forced respiration (if the scapula is fixed by the person tightly holding a horizontal bar).	• Medial pectoral nerve (C8,T1) • Lateral pectoral nerve may also supply this muscle (C5,6).
Subclavius	Junction of the first rib and its costal cartilage (Fig. 12.5A).	A groove on the middle-third of inferior surface of clavicle (Fig. 12.5B).	• Depression of clavicle • Keeps medial end of clavicle pressed against articular disc of sternoclavicular joint, and smoothens movements.	• Nerve to subclavius (C5, 6) arising from Erb's point (on upper trunk of brachial plexus)
Serratus Anterior	• Outer surfaces and upper borders of upper eight ribs. • Lower four digitations interdigitate with costal origins of external oblique of abdomen (Fig. 12.6).	• Along the medial border of the costal surface of scapula (Figs 12.7 and 12.8).	• Protraction of scapula (with pectoralis minor) as in punching and pushing movements. • Forward rotation of scapula (with trapezius), so that the glenoid cavity is turned upwards leading to overhead abduction of the arm.	• Long thoracic nerve of Bell-branch from roots C5,6,7 of brachial plexus • The nerve enters the axilla through its apex behind the first part of axillary artery and passes downwards along the medial border of axilla beneath the deep fascia.

Dissection

The muscles of the pectoral region should be studied only after a complete study of the mammary gland is made.

The platysma may be seen in the superficial fascia in the infraclavicular region. In rare cases, it may extend into the superior thoracic area. Since the cutaneous twigs are already seen, the fascia over the pectoralis major may now be cleaned. Its continuity to the axillary fascia should be seen and studied. The deltopectoral triangle, deltopectoral groove and cephalic vein should be made out and their significance recollected.

Identify the pectoralis major; clean it and try to put in your fingers underneath the muscle from the deltopectoral side. Cut across the muscle (using a scissors and not a scalpel) immediately below the clavicle, safeguarding the underlying structures by retaining your fingers underneath. Branches of lateral pectoral nerve and thoracoacromial artery can be seen to enter the muscle from underneath Slowly work through the rest of the muscle and cut it about 5 cm from the sternum. Reflect the major part of the muscle laterally towards the humerus. Pectoralis minor and clavipectoral fascia come into view. One or two twigs of medial pectoral nerve can be seen to pierce the minor muscle and then enter the undersurface of the major muscle. Try to preserve the various neurovascular structures.

Study the clavipectoral fascia and structures piercing it. Clean the fascia over the pectoralis minor. After defining the attachments of this muscle, cut through the clavipectoral fascia close to the clavicle. The subclavius muscle can now be seen. Follow the cephalic vein to the axillary vein; the lateral pectoral nerve and the thoracoacromial artery towards their proximal ends. The vessels of the axilla can then be looked for especially superior to the pectoralis minor.

Push in one or two fingers through the cut portion of the clavipectoral fascia and try to feel for the first rib and the scalenus anterior muscle.

Retracting various structures with gentle pressure, identify and study the several structures exposed.

Four of the above mentioned muscles, namely, pectoralis major, pectoralis minor, subclavius and serratus anterior are together called the ***anterior axio-appendicular*** (connecting the axial skeleton, i.e., trunk and the appendicular skeleton, i.e., upper limb) or thoraco-appendicular or thoracopectoral or pectoral muscles. They move the pectoral girdle.

Platysma

The platysma muscle lies in the superficial fascia. It arises from the deep fascia over the upper part of the pectoralis major and the anterior part of the deltoid. The fibres form a broad sheet that passes upwards and forwards across the clavicle to enter the neck. It then passes upwards and forwards to reach the lower border of the mandible, where it partly inserts into the lower border of mandible and partly merges with superficial muscles in the lower part of the face.

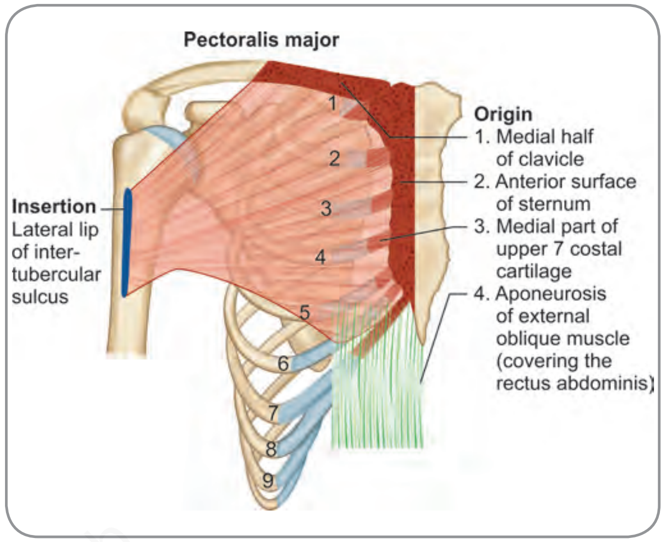


Fig. 12.3: Attachments of the pectoralis major

Additional notes on Pectoralis major (Fig. 12.3)

- It is a large fan shaped muscle that covers most of the upper part of the thorax.
- The sternocostal head of the muscle is larger than the clavicular head and forms the anterior wall of the axilla. The inferior border of this head forms the anterior axillary fold.
- A groove runs between the pectoralis major and the deltoid muscles; this narrow groove is called the ***deltopectoral groove***. The cephalic vein runs in this groove. However, where the two muscles diverge from each other superiorly, a small triangle called the deltopectoral (or the clavipectoral) triangle is formed.
- Mammary gland lies superficial to this muscle.

Additional notes on Pectoralis minor (Fig. 12.4)

- Though the pectoralis minor lies in the anterior wall of the axilla, it is completely covered by the larger pectoralis major
- The muscle is triangular in shape; the base is its origin and the apex is its insertion.
- It stabilises the scapula; when trying to stretch the upper limb to reach an object which is away, this muscle protracts the scapula while also stabilising it.
- It is an anatomical and clinical landmark; along with the coracoid process, this muscle forms an osseomuscular bridge under which pass the structures of the axilla.
- It separates the pectoralis major from the contents of the axilla.
- It lies in front of the axillary artery thereby dividing the artery into first, second and third parts.
- Its upper border gives attachment to the clavipectoral fascia, and is accompanied by the superior thoracic

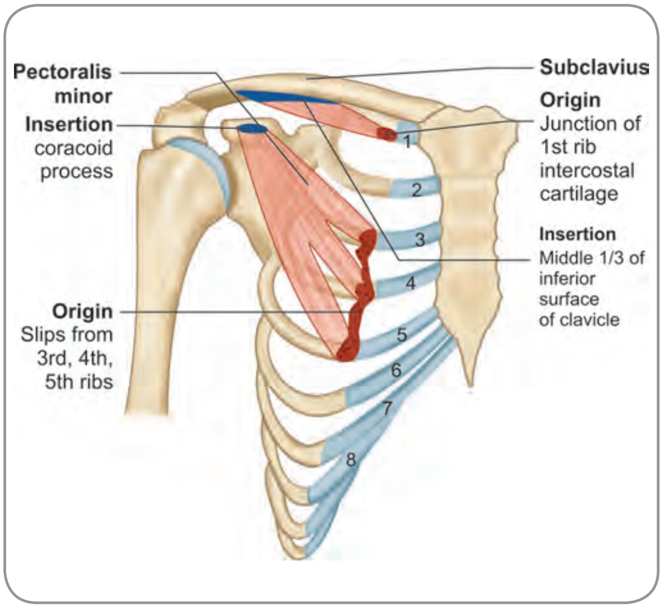
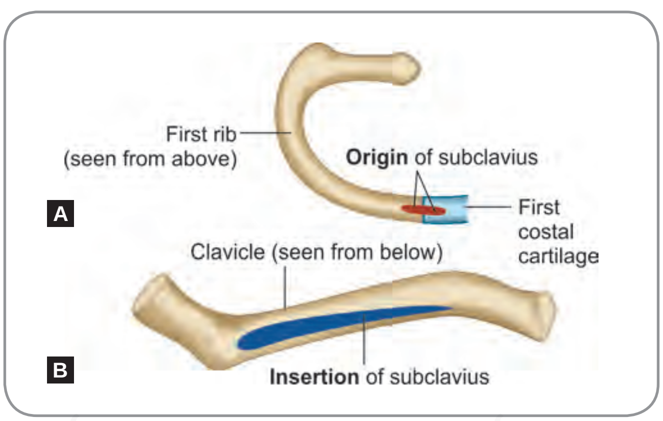


Fig. 12.4: Attachments of the pectoralis minor and of the subclavius

artery; its lower border gives attachment to suspensory ligament of axilla and is accompanied by lateral thoracic artery.

Additional notes on Subclavius

- This muscle lies horizontal in the anatomical position.
- Since it stabilises the clavicle, it also prevents dislocation of the clavicle at the sternoclavicular joint, which tends to happen while pulling hard on something (in the act of pulling, the lateral end of clavicle is taken backwards and to balance the force, the medial end tends to slip forwards) (Figs 12.5A and B).
- Though a small muscle, in cases of clavicular fracture, it tends to give some protection to the subclavian vessels and the superior trunk of brachial plexus.



Figs 12.5A and B: A. Superior surface of the first rib to show the origin of the subclavius **B.** Inferior surface of the clavicle to show the insertion of the subclavius

Dissection

Though the muscles of the region have been described for the student to be aware of information, in the practical class, the mammary gland should first be studied before the muscles are defined

The mammary gland can be seen only in female cadavers. Students allotted to male cadavers will have to move to a dissection table with a female cadaver Depending on the age and pre-death socioeconomic conditions of the cadaver, the structures of the mammary gland will be altered or modified. Lobes of the gland would have been replaced by fat in old age.

However, try to identify the suspensory ligaments, glandular tissue and fat between these ligaments,

Make a vertical (superior to inferior) cut through the nipple; probe bluntly at the cu edge; the lactiferous ducts can be made out converging on the nipple. Attempt to trace one lactiferous duct and its sinus. Trace the lobe of the duct. Try to insert a short narrow blunt probe into the opening of the lactiferous duct and study it.

As you study the glandular tissue of the mammary gland, try to insinuate your fingers with gentle force behind the breast tissue to open the retromammary space.

Additional notes on Serratus anterior (Fig. 12.6)

- This muscle forms the medial wall of the axilla. It covers the lateral part of the chest wall as a broad sheet.
- Its digitations from the chest wall produce a serrated appearance and hence the name 'serratus' (Latin. serratus=saw) (Figs 12.7 and 12.8).
- It is one of the most powerful muscles of the pectoral girdle.

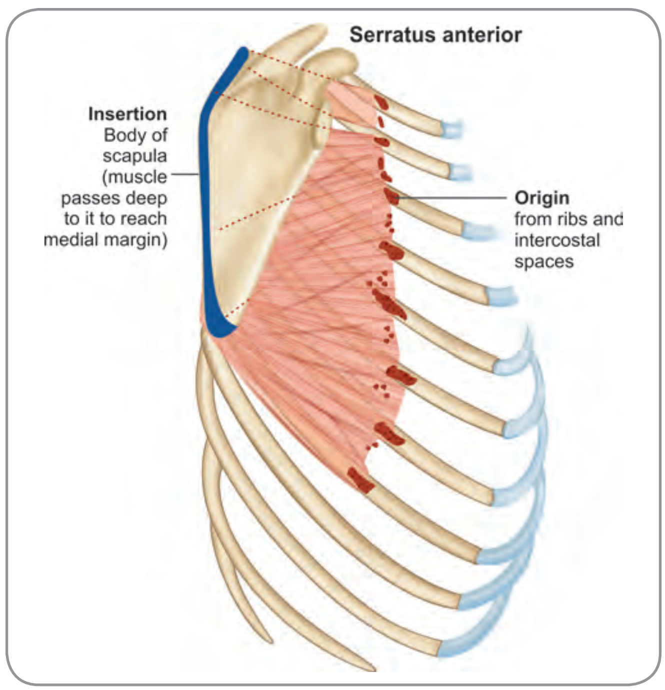


Fig. 12.6: Scheme to show the attachment of the serratus anterior

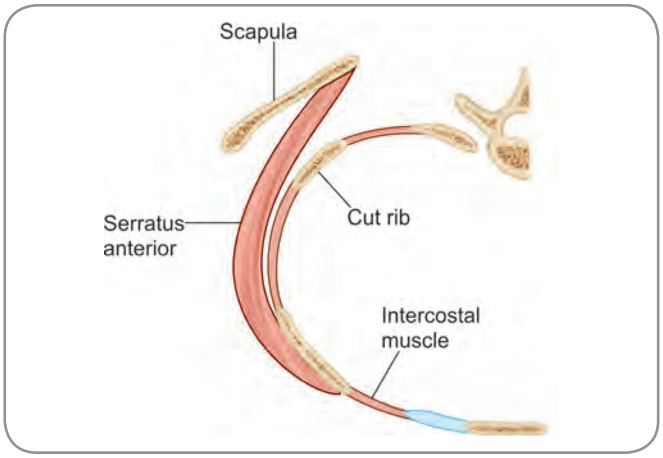


Fig. 12.7: Schematic diagram to show the relationship of the serratus anterior to the thoracic wall and to the scapula

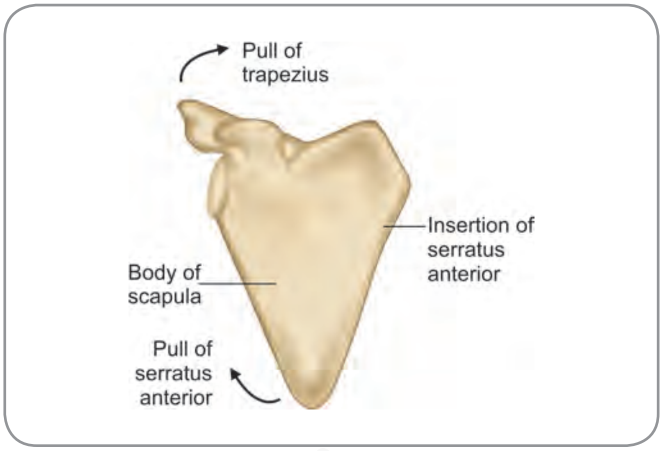


Fig. 12.8: Costal surface of the scapula showing the insertion of the serratus anterior – the lower arrow indicates the direction of pull in forward rotation of the scapula

- Since it is a strong protractor of the scapula and is used in pushing and punching movements, it is often called the '***boxer's muscle***'.
- It anchors the scapula, keeping it close to the thoracic wall This offers a mechanical advantage when movements of the humerus occur and the scapula remains fixed.

Clinical Correlation

- Pectoralis minor muscle acts as a surgical landmark in the identification of axillary lymph nodes during mastectomy surgeries for cancer of breast.
- Serratus anterior muscle is tested by making the patient place his palms against a wall and push against it. If the muscle is paralysed, the medial margin of the scapula is lifted off from the ribs. This is called ***winging of the scapula***. Overhead abduction of the arm is not possible Paralysis of the muscle usually occurs when the long thoracic nerve of Bell is injured during surgical removal of axillary lymph nodes.

MAMMARY GLANDS

Breast

Introduction

The mammary glands (also called the breasts in common parlance) are accessory organs of the female reproductive system. They are also the specialised accessory glands of skin which secrete milk. On the front of the chest wall on each side, overlying the pectoral region is a hemispherical elevation called the mamma or breast. Situated in the superficial fascia of the mamma is the mammary gland. The mammary glands are well developed in the females only after the age of puberty. In males and pre-pubertal females, they are rudimentary (Fig. 12.9).

Extent

The breast extends from the second rib to the sixth rib in the mid clavicular line.

Medially, it extends to the right or left margin of the sternum. Laterally, though its extent is variable, it may reach the midaxillary line.

Medial two-thirds of the base of breast lies over the pectoralis major; the lateral portion lies on the serratus anterior; inferiorly, it overlaps the external oblique muscle of the abdomen and its aponeurosis. These structures, which form a substratum for the mammary gland to rest are collectively called '***the mammary bed***'.

A ***retro-mammary space*** containing loose connective tissue separates the base of the breast from the deep fascia covering the mammary bed. Normal breast can be moved freely over the pectoralis major due to the presence of this space.

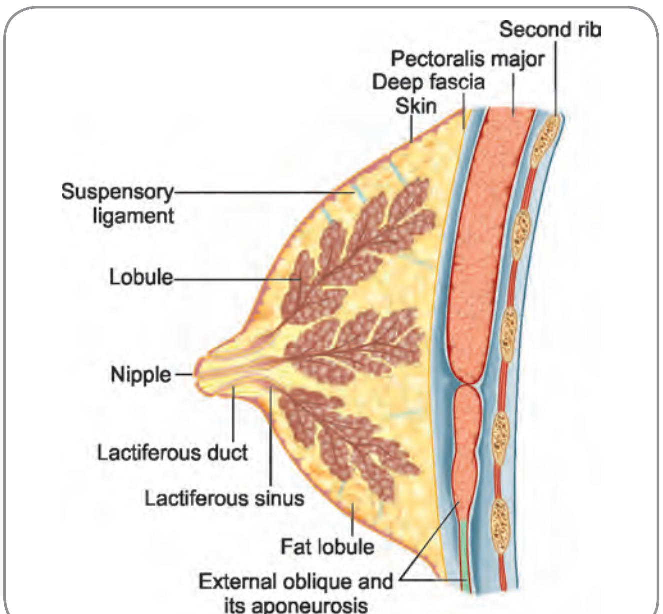


Fig. 12.9: Schematic vertical section through the breast

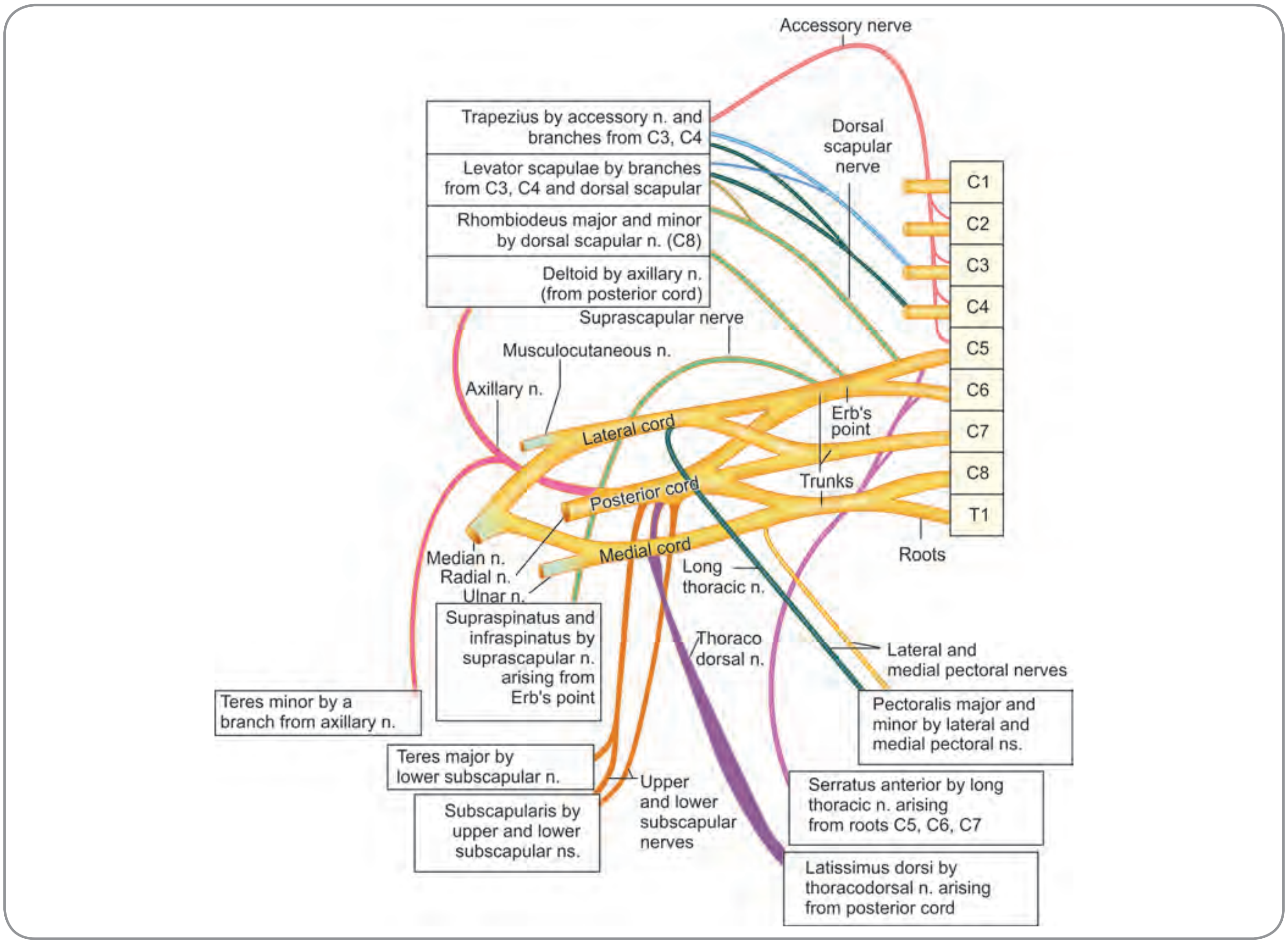


Fig. 12.10: Scheme to show nerve supply of muscles of upper limb, on the back and in the pectoral and scapular regions

From the upper lateral part of the gland, a prolongation of glandular tissue extends along the lateral border of pectoralis major and passes through an aperture in the deep fascia of axilla to enter the latter. This extension is called the ***axillary tail of Spence*** and the opening in the axillary deep fascia is the ***foramen of Langer***.

Over the centre on each side and near the summit (if the breast can be described as a cone fitted onto the anterior chest wall with its base and the apex or summit projecting forward), is the nipple. It is usually at the level of the fourth intercostal space though variations are common. The nipple is surrounded by a dark circular area called the ***areola***.

Structure

The structural composition of the breast can be understood in detail by studying the various components from the deeper to the superficial aspect. The mamma or breast is made up of a mass of glandular tissue ,which is supported and traversed by fibrous tissue. Their is lot of glandular and fibrous tissue , covered by a thick layer of fat and skin.

Glandular tissue: The glandular tissue is a conical mass; its base sits loosely on the deep fascia covering the deeper muscles; its apex corresponds to the position of the nipple. It is composed of fifteen to twenty ***lobes*** which radiate from the nipple. Each lobe is distinct from its neighbours and has its own duct called the ***lactiferous duct***. The lobes are separated from each other by strands of fibrous connective tissue which also has some fat. This interlobar connective tissue, in many places, extends from the overlying dermis to the underlying deep fascia and muscles. As a result, connective tissue strands appear to be suspending the mammary tissue from the muscles of the thoracic wall; hence, these are called the suspensory ligaments or ligaments of ***Astley Cooper*** (named after the 18th-19th century English surgeon – anatomist Sir Astley Cooper). They are defined as fibrous septa which anchor the glandular parenchyma to both the overlying skin and underlying muscles.

Fibrous tissue: As noted above, the fibrous tissue (strictly, fibro-fatty tissue) forms septa separating the lobes. It also subdivides each lobe into a number of lobules. Thus, the glandular parenchyma can be said to be supported by a

Histology

Histology of mammary gland

The mammary gland is a modified sweat gland. It is of the compound alveolar variety. Each lobe of the mammary gland can be described as an individual compound alveolar gland. Thus the mammary gland on each side is made up of a collection of 15 to 20 compound alveolar glands.

Each lobe is subdivided into several lobules by connective tissue. Each lobule has a cluster of alveoli. The alveolus is the secretory un t; it has a layer of columnar epithelium and drains into a small duct. Ducts from all the alveoli of the lobule join together to form a larger duct which in turn is joined by similar ducts from other lobules. A l the lobular ducts of a single lobe join to form the duct of the lobe, which is the lactiferous duct.

This basic histological pattern of the gland undergoes changes according to age and hormonal activity of the individual. In a small girl, only a rudimentary duct system exists and there are no alveoli. In a pre-pubertal girl, considerable deposition of fat occurs in the connective tissue. At puberty, the duct system undergoes extensive branching and more fat is deposited.

In a resting breast (post-pubertal but non lactating), the duct system is extensive; alveoli are practically absent; the intralobular connective tissue (that surrounding alveoli and ducts) is cellular and wide; the interlobular and interlobar connective tissue are wider, less cellular and have fat deposits.

During early pregnancy, ducts lengthen and branch further; secretory alveoli bud from the smallest ducts. As more and more alveoli bud, the lobule becomes larger in size and the intralobular and interlobular connective tissue thin out. Blood vessels in the connective tissue increase to provide for the developing glandular tissue. Alveolus has columnar epithelium and myoepithelial cells. In late pregnancy, the alveoli secrete protein rich serous colostrum and so, are enlarged. Many alveoli and ducts appear distended.

In lactation, alveoli are abundantly enlarged; connective tissue partitions are very much thinned out. The alveolar epithelial cells are columnar with convex luminal surfaces which bear microvilli. These cells have prominent lipid droplets, secretory (protein) granules (containing milk) and abundant organelles. They rest on a basement membrane which in turn rests on the surrounding connective tissue.

Post-lactation, due to the alveoli being non-secretory, they are small in size. After some time, some of the secretory alveoli are resorbed. Connective tissue partitions thicken once again.

Post-menopause, glandular and connective tissue elements atrophy. Ducts may close off due to cellular proliferation and in some ducts, cysts may be formed.

meshwork of fibrous tissue. This meshwork forms the stroma of the mammary gland.

Fat: A dense, thick layer of fat covers the stroma and the glandular parenchyma on the superficial aspect (thus lying between the skin on one hand and the stroma and parenchyma on the other). However, two important features of this fat should be remembered. Firstly, in the region of areola and nipple, this fatty covering is absent. So, it is easy for the lactiferous ducts to open into the nipple. Secondly, the fatty tissue acts as a filler. Each lobe, as noted already, is made up of a number of lobules. Because of the ups and downs produced by the lobules and the fibrous tissue in between, the superficial aspects of the lobes become uneven. The still superficial fatty covering sends in processes to fill the inequalities and offers a buffered support to the glandular parenchyma.

Skin: The nipple and the areola are specific features seen on the skin of the breast. The nipple, in fact, is a small conical projection in the centre of the areola. The skin of the nipple shows several wrinkles and that of the areola shows tiny rounded projections. The projections are due to a large number of modified sebaceous glands called the ***areolar glands***, which produce an oily secretion that lubricates both the areola and nipple. These glands become enlarged during pregnancy and produce surface elevations or tubercles called ***Montgomery tubercles***.

The lactiferous ducts open on the nipple by minute apertures. The nipple itself is richly innervated with sensory nerve endings and has a good number of smooth muscle fibres. Due to the presence of muscle fibres, mechanical stimulation causes the nipple to become more prominent and more firm.

The colour of the nipple and the areola vary not only from individual to individual (depending on one's complexion) but also in the same individual under different circumstances. In young individuals, they are rosy pink; during pregnancy they become brownish and continue to remain so, especially after the second pregnancy. The size of the nipple and the areola also increase during pregnancy.

The lactiferous ducts open into the nipple. They are found converging into the nipple from the radiating lobes. As a lactiferous duct passes to the nipple beneath the areola, it enlarges to form a fusiform dilatation called the lactiferous sinus. Becoming constricted after the dilatation, the duct proceeds to open to the surface at the summit of the nipple. The lactiferous duct of a lobe does not communicate with the ducts of other lobes.

Age changes

Since the breast is a secondary sexual organ, it is influenced by hormonal changes. In addition to microstructural changes, several other changes occur in the gross size, shape and appearance of the breast from time to time depending on the age and hormonal status of the individual.

- In pre-pubertal females, the breast is generally flat; areola and nipple are not well developed. With respect to the glandular tissue, only a few ducts are present and there are no alveoli.

- At the time of puberty, there is increase in size and is due to accumulation of fat. The duct system proliferates; however, alveoli do not appear.
- In post-pubertal females, the shape becomes hemispherical. Nipple and areola become larger and prominent. The ducts branch more; a few alveoli may have sprouted but remain as small sized solid spheroidal masses
- In pregnancy, considerable increase in size occurs due to internal changes. At the gross level, nipple enlarges; areola becomes darker and also enlarges in size. An increased deposit of melanin in the epidermis of areola is responsible for the darkening. The tiny tubercles of the areola enlarge due to increased activity in the areolar sebaceous glands. These glands provide lubrication to the nipple and areola. Internally, lengthening and branching of the ducts occurs rapidly. Some more alveoli may bud.
- In late pregnancy, there is further enlargement of breasts more due to accumulation of secretions in the alveoli. The growth rate of duct system decreases but the alveoli become secretory.
- In lactating females, the breasts are much enlarged; nipple and areola remain enlarged; Montgomery's tubercles are prominent. Alveoli are actively secreting.
- In the post lactating phase, there is some reduction in size. Secretory alveoli shrink and some of them disappear. The nipples shrink and the areola fades. However, the nipple and areola do not return to their original pre-pregnancy state
- During menopause and old age, the breast atrophies. Fat deposits tend to decrease and the total size is reduced. The breasts become pendulous. Internally, secretory elements regress; ducts remain but in shrunken state.

Blood Supply

The arterial supply can be described in three sets

1. The medial set of arteries
2. The lateral set of arteries and
3. The deep set of arteries.

The ***medial set*** is composed of arteries, which enter the gland from the medial aspect–these are twigs (called the medial mammary branches) from the perforating branches of the ***internal thoracic artery***. The internal thoracic artery lies within the thorax and runs downwards vertically, a short distance from the margin of the sternum. Perforating branches (also called the cutaneous branches) which are given out from it, perforate the thoracic wall and pectoralis major and reach the superficial fascia; their mammary branches enter the medial aspect of the mammary gland. These branches are large in the female, and hence the internal thoracic artery is also called the internal mammary artery. A few mammary branches may also be given out by the anterior intercostal arteries which are again branches of the internal thoracic artery.

The ***lateral set*** is composed of arteries, which enter the gland from the lateral aspect–these are twigs which are given out from the branches of axillary artery. Two branches of axillary artery, namely, the ***lateral thoracic*** and the ***thoracoacromial*** give out several branches (called the lateral mammary branches) to the gland. Twigs may be given out from the superior thoracic and subscapular branches of the axillary artery also.

Both the medial and the lateral set vessels, after entering the gland from their respective sides, ramify on the superficial aspect of the gland and send branches to the interior. Some branches also anastomose around the nipple.

The ***deep set*** is composed of arteries, which enter the gland from the deep aspect–these are the branches of ***intercostal arteries***; they pierce the thoracic wall and enter the gland from its deeper aspect.

Venous drainage from the breast is by veins corresponding to the arteries. These veins join the axillary and internal thoracic veins. That vein which accompanies the thoracoacromial artery joins the cephalic vein which in turn drains into the axillary vein. The posterior intercostal veins drain into the azygos and hemiazygos system of veins which communicate with the internal vertebral venous plexus.

Development

In an embryo, the ectoderm thickens longitudinally along a line running from the base of the forelimb bud to the medial aspect of the hind limb bud. This is the mammary ridge or milk line ridge. However, the ridge disappears except for a small portion in the pectoral region. By the 4th week of intrauterine life, a small patch of thickened ectoderm is seen in the area of the future gland. Soon this thickening becomes depressed into the underlying mesoderm. From the depressed ectoderm, solid cords develop and branch repeatedly. These represent the ducts. As the ducts divide and branch, the mesoderm around them condenses to form the stroma of the gland. With development of the stroma, the nipple gets everted. Just before birth, the ductal cord swells in the region of the future lactiferous sinus. Only around birth, lumina develop in the ductal cords.

Though the mammary ridge disappears in most of its length normally, in some individuals parts of it may remain and give rise to conditions like polythelia and polymastia.

Innervation of the Breasts

The nerves of the breast are derived from the anterior and lateral cutaneous branches of the fourth, fifth and sixth intercostal nerves from the ventral primary rami of thoracic spinal nerves. These branches pierce the

pectoral fascia over the pectoralis major and reach the subcutaneous region. They convey sensory fibres from the skin of the breast. Sensory innervation is richest in the areola and nipple. Sympathetic fibres are also conveyed by the nerves. These fibres supply the blood vessels and the smooth muscles which are present in the gland.

Lymphatic Drainage

As the mammary glands are frequent sites of carcinoma, their lymphatic drainage is of considerable importance. The lymphatic drainage of breast is usually divided into two sets:

- One set that drains the parenchyma, along with the skin covering the areola and nipple; and
- The other set that drains the overlying skin (excluding the areola and nipple).

However, the two sets of vessels are not exclusive of each other; they communicate with each other and drain predominantly into the same sets of lymph nodes.

Lymphatic drainage of the Parenchyma and the skin of Areola and Nipple

In the glandular parenchyma is an extensive plexus of lymph vessels. Since this plexus is denser around the lobules, it is sometimes called the perilobular lymphatic plexus. Many of the vessels arising from the perilobular plexus communicate with another dense plexus called the subareolar plexus (plexus of Sappey) lying beneath the skin of areola and nipple (Fig. 12.11).

- Efferent lymph vessels from the subareolar plexus pass in a lateral direction to drain predominantly into the ***anterior (pectoral) group of axillary lymph nodes*** with a few draining into the posterior group too. Lymph from the anterior and posterior groups then passes to the central group and from there to the apical group of axillary lymph nodes (it is essential to remember that free communication exists between all the groups of axillary nodes)—70 % of the total drainage.

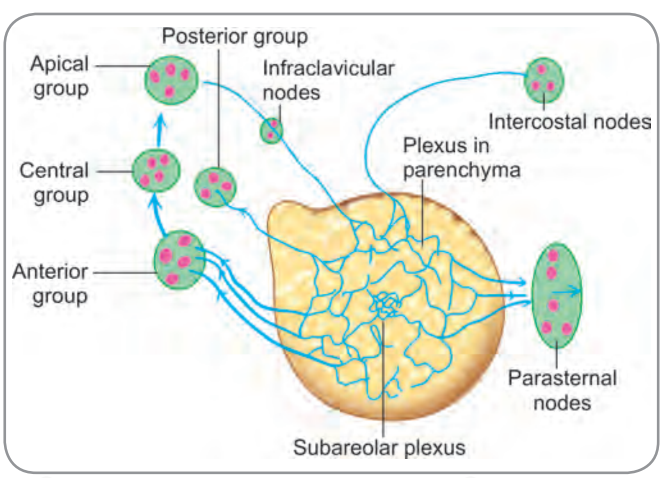


Fig. 12.11: Scheme to show the lymphatic drainage of the parenchyma of the breast and of the skin of the areola and nipple

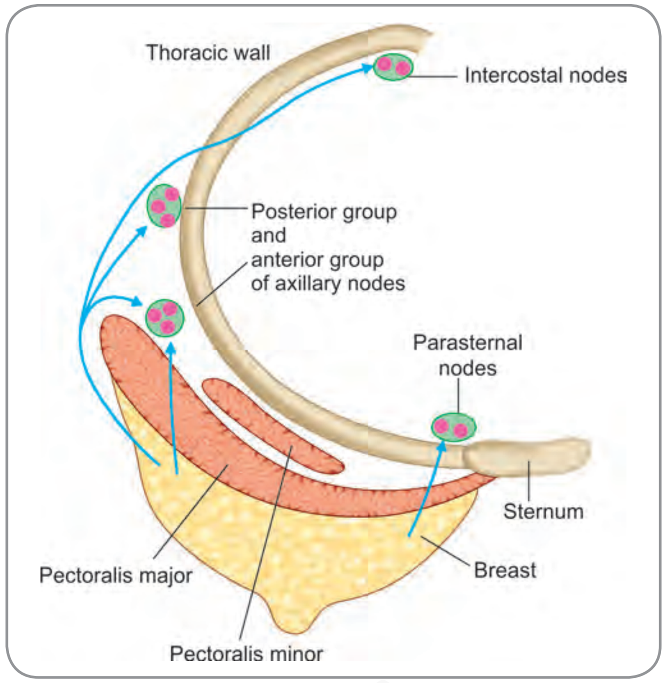


Fig. 12.12: Scheme to show routes followed by lymphatic vessels draining the breast

- Lymph vessels from the superior and superolateral parts of the parenchyma pass directly to the apical group and also to the infraclavicular lymph nodes—5 % of the total drainage.
- Some vessels from the medial part of the gland follow the path of the branches of the internal thoracic artery and drain into the ***parasternal nodes*** present along the artery within the thorax—20 % of the total drainage.
- A small percentage of lymph vessels reach the ***intercostal nodes*** lying within the thorax near the posterior ends of the intercostal spaces. These vessels travel backwards along the lateral cutaneous branches of the posterior intercostal arteries—5 % of the total drainage (Fig. 12.12).

Lymphatic drainage of skin of Breast (excluding that of Areola and Nipple) (Fig. 12.13)

The main drainage from the skin is into the same nodes that drain the parenchyma viz., laterally, the anterior group of axillary nodes and medially, the parasternal nodes.

- Some vessels from the upper part of the skin cross the clavicle and reach the lowest nodes of the deep cervical chain. These nodes lie just above the clavicle and are, therefore called the ***supraclavicular lymph nodes***.
- Some vessels from the lower part of the breast drain into the sub-diaphragmatic nodes and hepatic nodes
- Some of the cutaneous lymphatics of the medial side communicate across the midline with those of

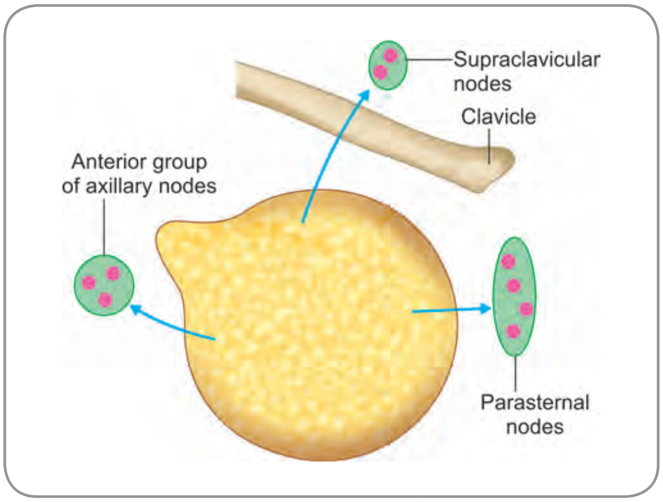


Fig. 12.13: Lymphatic drainage of the skin of the breast (excluding that over the areola and nipple)

the opposite breast and with those of the anterior abdominal wal .

Added Information

- The nipples have no hair, fat or sweat glands
- Circularly arranged smooth muscle fibres are found underneath the nipple. These muscles, on contraction cause compression of the lactiferous ducts and aid in lactation.
- Since the mammary glands are modified sweat glands, they have no capsule or sheath.
- Clinical description of the breast is by quadrants. Four quadrants, namely, superomedial, superolateral, inferomedial and inferolateral are marked out. All the quadrants and the entire circle formed by them are superimposed to the imaginary figure of a clock. Thus, descriptions like 'a mass in the superomedial quadrant at the 2 o' clock postion' or ' an irregularity in the inferolateral quadrant at the 8 o' clock position' are commonly heard.

Clinical Correlation

- Inflammation of the breast is called ***mastitis***. It may be acute or chronic. Mastitis can lead to abscess formation. Traditionally, radial incisions have been advised for drainage of an abscess in the breast (to avoid injury to the lactiferous ducts which also run radially). However, such incisions are disfiguring and incisions along the junction of the areola and nipple are now preferred.
- ***Cysts***, multiple or single, may be formed by obstruction of ducts. A milk-containing cyst is called a ***galactocoele***.
- Congenital anomalies like polythelia (multiple accessory nipples) can occur. Supernumerary nipples are seen along the original ***'milk line'***. Very rarely accessory nipples may be found in the axilla or anterior abdominal wall. Polymastia is the condition of supernumerary breasts. Such breasts usually present like small moles with a rudimentary nipple and little areola around. If any glandular tissue in present in a supernumerary breast, it may get enlarged and start secreting milk during lactation.
- ***Amastia*** is a condition where there is no breast development. There may be a nipple and even areola, but there is no glandular tissue.
- The breast can be smaller than normal, such condition being called ***micromastia*** or larger than normal (especially in males) called ***gynaecomastia***. In some cases the cause of gynaecomastia is idiopathic(cause not known). Pathological causes of gynaecomastia include liver disease, hormone secreting tumours, leprosy and side effects of some drugs. Gynaecomastia is one of the characteristic features of the XXY chromosomal anomaly called Klinefelter's Syndrome.
- ***Retracted nipples:*** In this condition, the nipple is not prominent and protracted out as it normally should be; instead, it lies in a pit. Congenital retracted nipple is due to failure in the development of nipple. Acquired retracted nipple is usually due to an underlying carcinoma that pulls on the lactiferous ducts causing the nipple to recede.
- The clinical importance of the suspensory ligaments (which truly are the interlobar septa) is multifold. Apart from anchoring and supporting the glandular tissue, they also partition it into several lobes. The mammary gland is prone to infection during lactation. Microorganisms enter the breast through cracks in the nipple. However, in the initial stage the organisms are usually confined to one lobe due to the septa. It is easy to treat the infection at this stage. Even if an abscess develops, the particular lobe can be drained off to avoid the infection from spreading to adjacent compartments. A radial incision is made for this draining of the abscess. The incision will remain localised o a particular compartment and spread is prevented.
- ***Mammography:*** This is a radiographic examination of breast tissue. Low doses of X-rays are used. Very small lesions measuring only a few millimetres (which cannot be felt or diagnosed by clinical examination) can be diagnosed by this method. A carcinoma appears as an area of rough density in a mammogram. Skin thickening, minimal retraction of nipple can all be made out clearly thus giving ample information for proper diagnosis. Mammography can also be used for post-surgical evaluation
- Masses in the breast may be caused by ***neoplasms*** (***tumours***). Both benign and malignant tumours are common in breast. Benign breast tumours are called ***fibroadenomas***.
  - Unlike a normal breast which is freely movable over the underlying structures, in carcinoma of the breast, the suspensory ligaments may be invaded by cancer cells and may sho ten leading to fixation of the breast to the underlying structures. The skin may get retracted at the attachments of these ligaments.
  - Knowledge of the lymphatic drainage of breast is very important when dealing with carcinoma of breast. In addition to the spread of cancer cells to areas of regular drainage (axillary and parasternal lymph nodes), they may also spread to the abdominal cavity (sub-peritoneal plexus). Further, cancer cells from the sub-peritoneal plexus may drop into the general peritoneal cavity, undergo transcoelomic migration and produce secondary deposit called ***Krukenberg's tumour*** on the surface of ovary.

contd...

Clinical Correlation *contd...*

- Although the lymphatics of the breast communicate with those lying on the deep fascia (covering the pectoralis major), this is not a normal route for drainage of lymph from the breast. However, if the superficial channels are blocked (by carcinoma), lymph may pass through these communications.
- Obstruction of superficial lymphatics can lead to oedema of the skin resulting in an appearance like that of an orange peel ***(peau d' orange*** appearance).
- In addition to spread through lymphatic vessels, cancer of the breast can occasionally spread through veins. Since the azygos system communicates with the vertebral venous plexus, cancer spread can occur through this route to vertebrae and from there to cranium and brain.
- Metastasis (spread) of cancer can also occur by contiguity; cancer cells invade adjacent tissues and get deposited in them. Retromammary space, pectoral fascia and interpectoral nodes are thus invaded.
- More than 60 % of breast cancers occur only in the lateral part of the gland and so the axillary nodes are involved. Since the axillary nodes can easily be removed surgically, it is comparatively easy to treat. However when the normal lymphatic pathway to the axillary area is blocked by tumour cells or the lymphatics damaged by surgery or radiotherapy, cancer spreads to the opposite side and abdominal area through the communicating lymphatics which now become the route of lymph flow.
- Surgical removal of breast is called ***mastectomy***. Removal of the breast tissue alone is ***simple mastectomy***. In localised cancer without any spread, even a lobectomy, lumpectomy (only the tumour mass and minimal adjoining tissue are removed) or quadrantectomy (removal of the concerned quadrant) can be performed to remove the primary tumour. The latter operations are called breast conserving surgeries.
- In the past, extensive surgery involving removal of entire breast tissue, large area of skin over the gland including the nipple and areola, all the axillary lymph nodes along with the fat and fascia of axilla, pectoralis major and minor muscles with their fasciae and all adjacent connective tissue including fasciae over serratus anterior, rectus sheath and latissimus dorsi was performed in an effort to remove all possible cancer cells. Such an operation was called ***radical mastectomy***. The patients go in for oedema of the arm or the entire upper limb after such an extensive radical surgery because the lymph vessels draining the upper limb have been removed. Most surgeons have now given up the traditional radical operation. In most cases only simple removal of the breast along with removal of axillary lymph nodes (partial radical mastectomy) is undertaken. Sometimes, the pectoralis minor is removed Surgery is followed by radiotherapy (exposure to X-rays which kill cancer cells) or hormone therapy.

- ***Physiological gynaecomastia*** in males occurs around the time of puberty (age of 10 to 12 years). It is rare after puberty. If it occurs, it is due to hormonal changes or imbalances (changes in the hormonal metabol sm due to liver diseases) or drugs (example being treatment given for prostatic cancer). Gynaecomastia in post-pubertal men should be regarded as a disease symptom and properly evaluated.

Multiple Choice Questions

1. The raising up of the axillary floor into a dome is due to:
   a. Stretching of axillary fascia across the base of axilla
   b. The triangular shape of axilla
   c. Attachment of clavipectoral fascia to axillary fascia
   d. Splitting of clavipectoral fascia to enclose the pectoralis minor

2. The following about deltopectoral groove are true except:
   a. The cephalic vein runs in it
   b. It joins the apex of the clavipectoral triangle
   c. It is between deltoid and pectoralis major
   d. It is supraclavicular in position

3. Serratus anterior
   a. Has muscular serrations as it joins the scapula
   b. Forms the lateral wall of axilla
   c. Helps in retraction of scapula
   d. Anchors the scapula for humerus to be moved

4. Ligaments of Astley Cooper:
   a. Are interlobar connective tissue strands of mammary gland
   b. Are enlargements of sebaceous glands
   c. Are adhesive connections of lactiferous ducts
   d. Are fibrous strands connecting lactiferous sinus to underlying deep fascia

5. The medial set of arteries to mammary gland are from:
   a. Internal thoracic artery
   b Superior epigastric artery
   c. Thoracoacromial artery
   d. Posterior intercostal arteries

ANSWERS

1. c **2.** d **3.** d **4.** a **5.** a

Clinical Problem-solving

Case Study 1: A 37-year-old woman presents with a small lump in the superolateral quadrant of her right breast. No other abnormality, swelling or discoloration is noted. Her doctor orders for some investigations.

- In physical examination, which area / region should definitely be examined apart from the local region?
- If the woman has malignancy, what is the possibility of her having a spread to the opposite side? Give reason for your answer.
- Which investigation would you ask for? And why?

Case Study 2: A medical student was observing some coolies on the street. One of them was trying to stand in front of a wall and rest a little. As the man was pushing his upper limbs on the wall, the medical student noticed that there 'winging of scapula' on the right side.

- What is 'winging of scapula'?
- Which nerve is affected in this condition?
- List out reasons for injury to the nerve.

(For solutions see Appendix).

Chapter 13

Axilla

Frequently Asked Questions

- Discuss the axilla in detail with reference to its boundaries, contents and applied importance.
- Discuss the axillary artery in detail with reference to its course, branches and relations. Add notes on its clinical significance and surface marking.
- Discuss the axillary lymph nodes and give their clinical significance.
- Discuss the brachial plexus in detail with regard to its formation, relations, cords, branches and distribution. Add notes on Erb's and Klumpke's paralyses
- Write notes on (a) Erb's point, (b) Prefixed and postfixed brachial plexuses, (c) Branches of medial cord of brachial plexus, (d) Branches of lateral cord of brachial plexus, (e) Branches of posterior cord of brachial plexus, (f) Musculocutaneous nerve, (g) Axillary nerve, (h) Klumpke's paralysis, (i) Cervico axillary canal.

The axilla is the region of the armpit. It is a pyramidal shaped space between the upper part of arm and the lateral thoracic wall. It is inferior to the shoulder joint. The anatomy of axilla is important because it serves as a passage for the major neurovascular structures of the upper limb.

BOUNDARIES OF AXILLA

The pyramidal space has an apex, base and four walls namely—(1) anterior, (2) posterior, (3) medial and (4) lateral (Fig. 13.1).

- ***Apex:*** It is triangular in shape and is bounded in front by the clavicle, behind by the upper border of scapula and medially by the outer border of first rib. It faces upwards and somewhat medially. Structures passing through the apex are the axillary vessels, cords of brachial plexus (both ensheathed with the axillary sheath which is derived from the prevertebral layer of deep cervical fascia), long thoracic nerve and efferent lymph vessels from the axillary lymph nodes. As these structures pass between the neck and the axilla, the apex of axilla is also called the ***cervicoaxillary canal*** (passage between neck and axilla; Greek.cervix=neck).
- ***Base:*** It is directed downwards and forms the floor of the axilla. It is actually the skin stretching between the anterior and posterior walls. Since the medial and lateral walls of axilla are of different dimensions, in line with that, the base is broad at the chest (medial wall) and narrow at the arm (lateral wall). It is convex upwards in conformity with the concavity of the armpit. It is bounded anteriorly by the anterior axillary fold, posteriorly by the posterior axillary fold and medially by the chest wall. However, superficial fascia and axillary fascia lying deep into the skin are also considered part of the base.
- ***Anterior wall:*** It is formed by the pectoralis major, the pectoralis minor, clavipectoral fascia and the subclavius. The ***anterior fold*** of the axilla is the inferior part of the anterior axillary wall and can be gripped

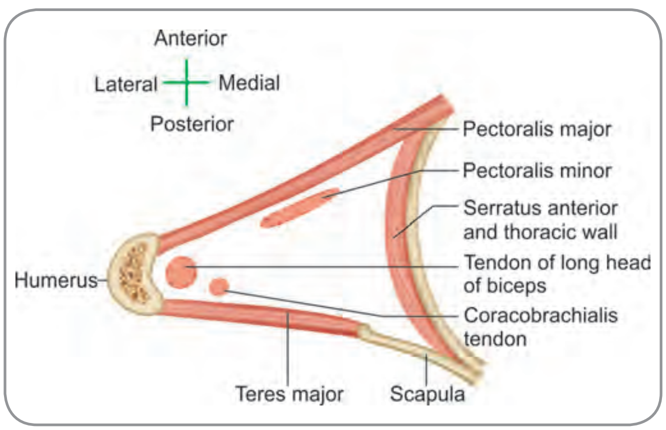


Fig. 13.1: Section of axilla showing the four walls

between fingers. It is formed by the pectoralis major, as the muscle runs from the thoracic wall to the humerus (Fig. 13.2).

- ***Posterior wall:*** It is formed by muscles lying in front of the scapula , which are (from above downwards) the subscapularis, teres major and the latissimus dorsi. The latissimus dorsi winds around the lower margin of the teres major and the two together form the thick ***posterior fold*** of the axilla. The posterior wall extends farther below than the anterior wall (Fig. 13.3).
- ***Medial wall:*** It is formed by the upper five ribs and the intercostal spaces, which are covered by the upper part of the serratus anterior muscle and the fascia covering it. The long thoracic nerve passes deep into the fascia covering the muscle. Intercosto brachial nerve which is the undivided lateral branch of the second intercostal nerve pierces this wall to supply the postero medial part of the arm (Fig. 13.4).

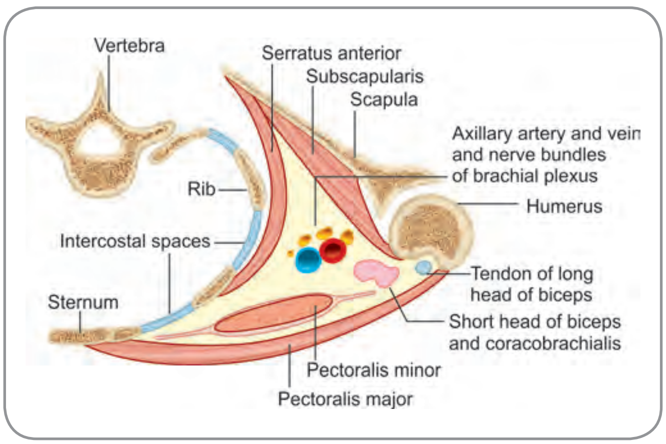


Fig. 13.2: Transverse section through the axilla to show its walls

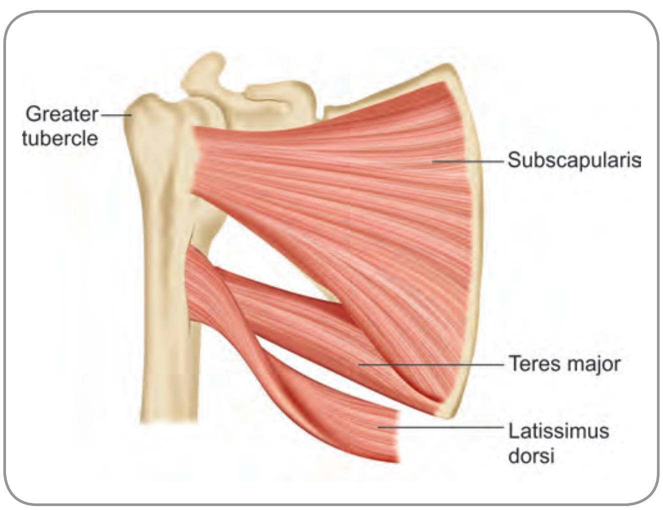


Fig. 13.3: Posterior wall of axilla

The latissimus dorsi as it winds around the teres major forms the posterior axillary fold

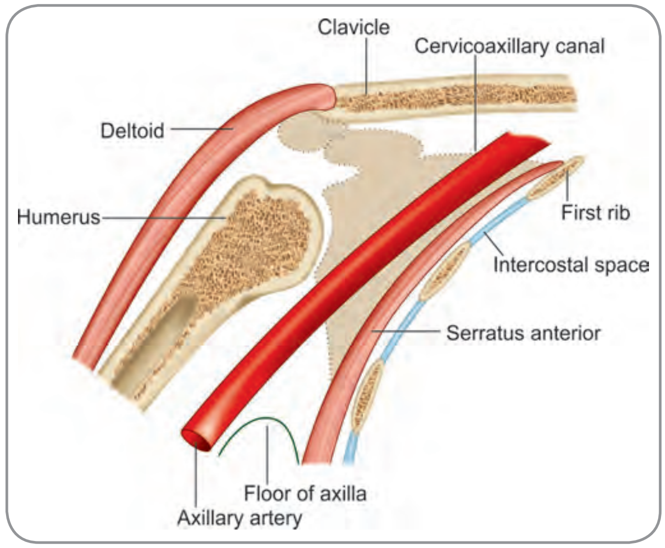


Fig. 13.4: Schematic coronal section through the axi la to show its medial and lateral walls

- ***Lateral wall:*** It is formed by the intertubercular sulcus of the humerus. The long head of biceps brachii that is lodged in this sulcus and the fibres of coracobrachialis which pass through the area are also included as part of the lateral wall (Fig. 13.4).

Contents of Axilla

The axilla contains all the major vessels and nerves which go to the upper limb. The lymph nodes which lie embedded in the fat of axilla drain the lymphatics of the upper limb. Thus, the axilla assumes extreme importance while dealing with the structures of the upper limb. The contents are:

- The axillary artery and vein,
- The cords of brachial plexus with their branches,
- The long thoracic nerve,
- The intercosto brachial nerve and
- The axillary lymph nodes.

All these structures are embedded in axillary fat.

Added Information

The medial and posterior walls of the axilla have bones overlaid with muscles; the lateral wall is bony; and only the anterior wall is devoid of bones and is fleshy. Hence, approaches to axilla are usually through the anterior wall or through the base which is practically fascial.

Clinical Correlation

Axilla is one of the sites prone for infection leading to abscess formation. It is usually drained through its base, at which time the vascular relations of the walls of the axilla have to be borne in mind.

AXILLARY ARTERY

The axillary artery is the continuation of the subclavian artery. It begins at the outer border of the first rib and ends at the lower border of the teres major (by becoming the brachial artery).Throughout its course, the artery is accompanied by the axillary vein , the cords and branches of brachial plexus. A covering derived from the prevertebral layer of deep cervical fascia called the axillary sheath encloses the proximal parts of the axillary artery, vein and brachial plexus. The artery is crossed by the pectoralis minor which divides the artery into three parts— (1) first part proximal to the muscle, (2) second part behind and (3) third part distal to the muscle (Fig. 13.5).

Dissection

Axilla can be dissected after studying the pectoral region.

The pectoralis minor muscle is cleaned and its undersurface separated from underlying structures by a blunt dissection with the dissector's fingers.

Connective tissue, fat and lymph nodes of the axilla are cleaned up and the contents of axilla exposed. Identify the coracobrachialis and the short head of biceps. Medial to these muscles are seen the axillary artery and the median nerve. Look for the musculocutaneous nerve as it pierces the deep surface of the co acobrachialis.

Medial to the artery is the axillary vein. Once you identify the axillary vein, look for the medial cutaneous nerve of forearm and the ulnar nerve in the gap between the axillary artery and the vein. The medial cutaneous nerve of arm can be seen medial to the vein.

Clean the axillary vessels. Locate the various nerves in the region. Identify the different cords of the brachial plexus around the axillary artery.

Cut the pectoralis minor if necessary. Expose the subscapularis and identify the subscapular nerves close to it.

Do a detailed study of the brachial plexus by repeatedly tracing the various nerves to their points of origin.

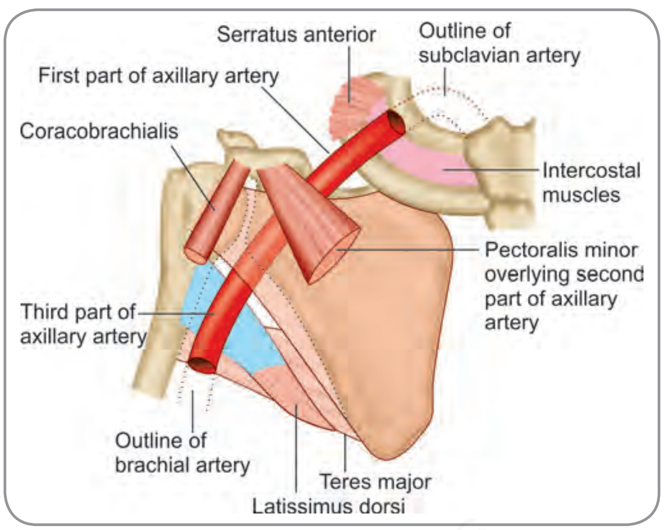


Fig. 13.5: Muscles related to the axillary artery

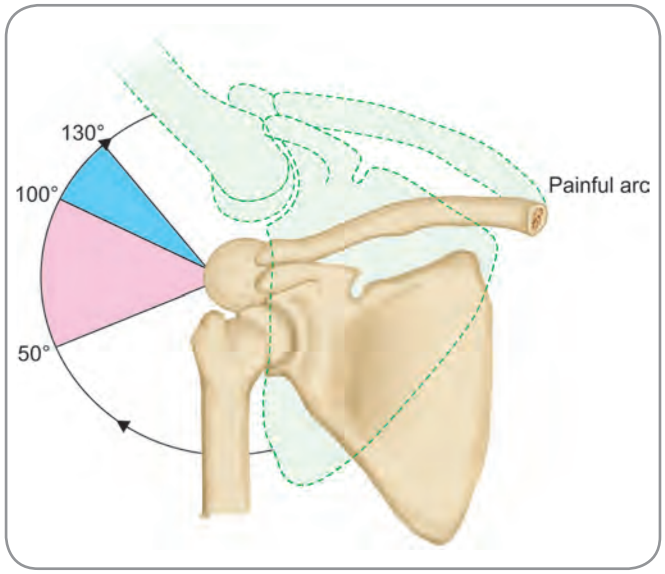


Fig 13.6: Impingement of the diseased area on the acrominon—middle arc of abduction is painful

Surface Marking: The arm is abducted to the level of the shoulder (that is to a right angle). Point A is marked on the middle of clavicle. Point B is marked on the medial border of the prominence of coracobrachialis. These two points are joined by a broad line that marks the axilllary artery. In the abducted position, the artery is straight. If the arm is hanging by the side of trunk, the artery will have a curved course with the concavity directed downwards and medially (Fig. 13.5).

Parts of the Axillary Artery (Fig. 13.7)

First part: This is the part of the artery from the outer border of the first rib to the medial border of pectoralis minor. It is enclosed in the axillary sheath and gives out one branch, the superior thoracic artery (Figs 13.8A and B).

Relations of the First Part

Anterior: (from superficial to deep) Skin, superficial fascia with platysma and supraclavicular nerves, pectoralis major, clavipectoral fascia (Fig. 13.9), loop of communication between the medial and lateral pectoral nerves, cephalic and thoraco-acromial vein and anterior wall of axillary sheath.

Posterior: First 2 digitations of serratus anterior, long thoracic nerve, medial cord of brachial plexus with the medial pectoral nerve.

Lateral: Lateral and posterior cords of brachial plexus.

Medial: Axillary vein.

Second part: This is the part that lies posterior to the pectoralis minor muscle. It gives out two branches, the thoracoacromial and lateral thoracic arteries.

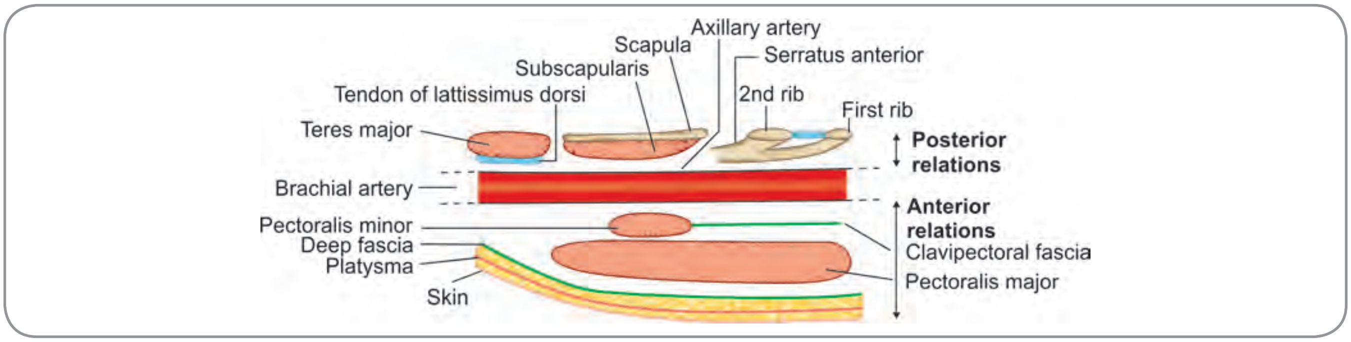
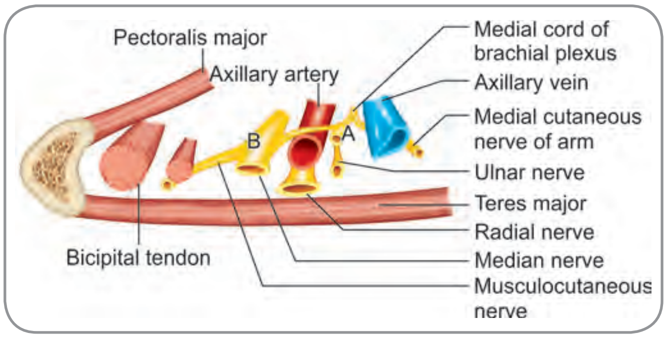


Fig. 13.7: Schematic longitudinal section along the course of the axillary artery



Figs 13.8A and B: Section of axilla showing the contents in relation to each other **A.** Medial cutaneous nerve of forearm **B.** Lateral cord of brachial plexus

The medial root of median nerve can be seen crossing the artery

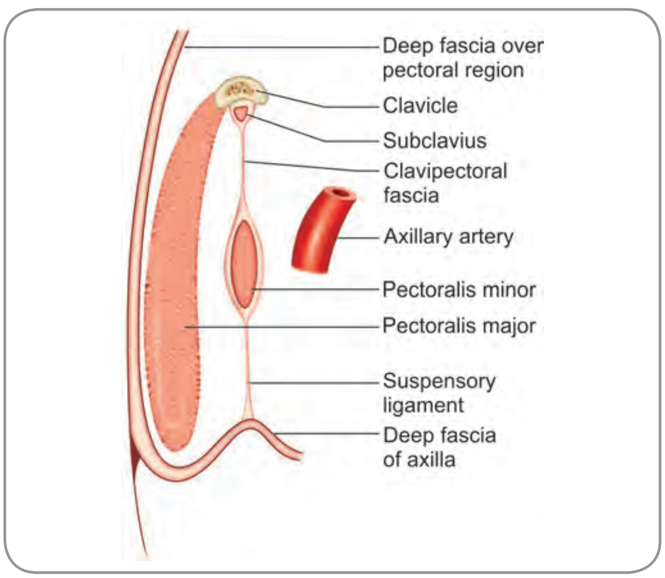


Fig. 13.9: Pectoralis muscles and clavipectoral fascia

Relations of the second part

Anterior: (from superficial to deep) Skin, superficial fascia, pectoralis minor and pectoralis major

Posterior: Posterior cord of brachial plexus and subscapularis muscle

Lateral: Lateral cord of brachial plexus

Medial: Medial cord of brachial plexus

Third part: This is the part of the artery extending from the lateral border of pectoralis minor to the lower border of teres major. It gives out three branches.

Relations of the Third Part

Anterior : Pectoralis major in the upper portion of third part; skin and superficial fascia in the lower portion. The medial root of the median nerve crosses the artery in the lower portion.

Posterior: Subscapularis, lattisimus dorsi and teres major muscles. The axillary and the radial nerves also lie posterior to the artery and between it and the muscles.

Lateral: Coraco brachialis and biceps muscles; lateral root and trunk of the median nerve and the musculocutaneous nerve lie lateral to the artery but medial to the muscles. Humerus is the most lateral relation to this part of the artery.

Medial: Axillary vein; between the artery and vein, are the medial cutaneous nerve of forearm in front and ulnar nerve behind; still medial to the axillary vein, is the medial cutaneous nerve of arm which receives communication from the intercosto brachial nerve.

Branches of the Axillary Artery (Fig. 13.10)

Branch of First Part

Superior thoracic artery: The superior thoracic artery (sometimes called the ***highest thoracic artery*** or the ***supreme thoracic artery***) is the only branch from the first part of axillary artery. It arises immediately below the subclavius and passes posterior to the axillary vein. It runs anteromedially along the upper border of the pectoralis minor muscle; passes between the two pectoral muscles to the thoracic wall enroute supplying both of them. It also supplies the subclavius, superior slips of serratus anterior and part of the thoracic wall.

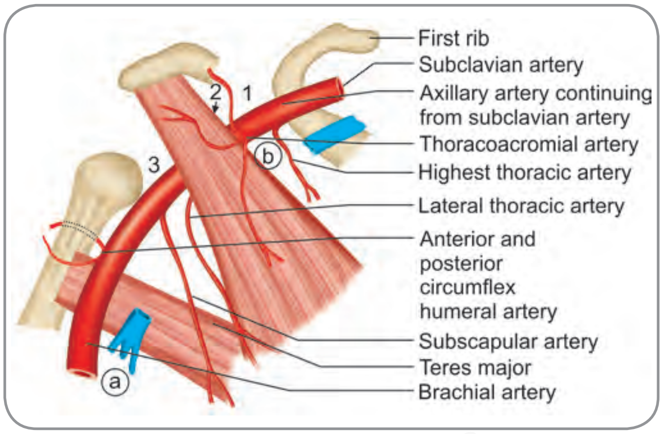


Fig. 13.10: Parts and branches of axilla y artery

a. Formation of colour of vein by union of brachial venae comitantes and basilic vein at lower border of teres major **b.** Thoracoacromial artery dividing immediately into terminal branches

1, 2, 3–first, second and third parts of axillary artery

Branches of Second Part

- ***Thoracoacromial artery:*** It arises deep into the medial margin of the pectoralis minor and runs upwards to become superficial by piercing the costocoracoid membranous part of the clavipectoral fascia It divides into four branches namely— (1) pectoral, (2) acromial, (3) clavicular and (4) deltoid; all the branches ramify in the plane between the clavipectoral fascia and pectoralis major (Fig. 13.11).
  - The ***pectoral branch*** descends between the pectoral muscles, supplying them and the chest wall.
  - The ***acromial branch*** passes laterally. It first lies deep into the deltoid muscle and then pierces it to reach the acromion where it anastomoses with various other arteries.
  - The ***clavicular branch*** runs upwards to supply the subclavius and the sternoclavicular joint.
  - The ***deltoid branch*** runs laterally in the groove between the deltoid and the pectoralis major.

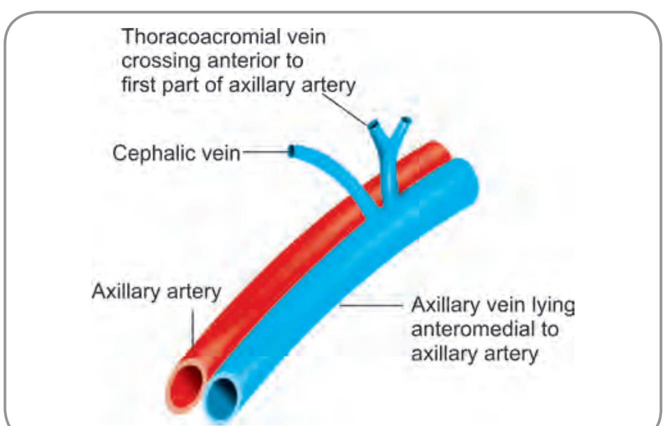


Fig. 13.11: Veins related to the axillary artery

- ***Lateral thoracic artery:*** Arising from behind the pectoralis m nor, it runs downwards along the lateral margin of the muscle to reach the thoracic wall, supplying enroute the pectoral muscles, the serratus anterior and the axillary lymph nodes. In the female, it gives off prominent lateral mammary branches to the breast.

Branches of Third Part

- ***Subscapular artery:*** It is the branch of the third part with the shortest length but the greatest diameter. It is also the largest branch of any part and is also called the artery of posterior axillary wall. Running downwards along the lateral border of the scapula, it supplies the muscles in the region and anastomoses with various other arteries In its lower part, it gives off a large ***circumflex scapular*** branch and then continues as the thoraco dorsal artery which accompanies the nerve to the latissimus dorsi (otherwise called the thoracodorsal nerve) and enters the muscle. The circumflex scapular branch winds around the lateral border of the scapula and passes backwards to the infraspinous fossa; it gives branches to muscles on both the ventral and the dorsal aspects of scapula and takes part in forming the anastomosis around the scapula.
- ***Anterior circumflex humeral artery:*** It runs laterally in front of the surgical neck of the humerus, where it anastomoses with the posterior circumflex humeral artery to form an arterial circle round the neck. It gives off a branch that ascends in the intertubercular sulcus to the shoulder joint.
- ***Posterior circumflex humeral artery:*** Accompanied by the axillary nerve, the posterior circumflex artery runs backwards through the quadrangular space.It then passes laterally behind the surgical neck of humerus to anastomose with the anterior circumflex humeral artery. It also gives off a descending branch that anastomoses with a branch of the profunda brachii artery.

Clinical Correlation

- Pressure can be applied over the axillary artery near its lower end, at a level, just above the lower border of the posterior fold of the axilla, to stop bleeding distally. The artery can also be compressed against the humerus.
- The artery may also be compressed near its commencement; downwards pressure should be exerted in the angle between the clavicle and the lower attachment of sternocleidomastoid.
- Aneurysm of the first part of the artery compresses the trunks of brachial plexus resulting in pain and altered sensation over the area supplied by the concerned nerves. Rapid and extremely forceful movements executed by sportspersons cause the aneurysm.
- The anastomoses around the scapula links the subclavian artery with the third part of the axillary artery and serves to maintain circulation in case of blockage of the axillary artery. The collateral circulation is effective in gradual obstruction, but in sudden ligation it is inadequate.
- Axillary artery is also used for coronary bypass graft.

AXILLARY VEIN

The axillary vein accompanies the axillary artery through the axilla. It is formed at the lower border of teres major by joining together of the venae comitantes of the brachial artery and the basilic vein. It ends at the outer border of the first rib and continues as the subclavian vein. The axillary vein receives the cephalic vein and veins accompanying the branches of the axillary artery (Fig. 13.12).

The vein lies medial to the axillary artery. The following structures intervene between the artery and vein:
- Medial cord of the brachial plexus
- Medial pectoral nerve
- Ulnar nerve

The medial cutaneous nerve of the arm is medial to the axillary vein.

Surface Marking: The points to be marked are as same as those for marking the axillary artery. However, the line indicating the axillary vein should be drawn a little medial to that would be drawn for the artery.

Added Information

- Veins of the axilla are many and variable. Most of the veins accompanying branches of the axillary artery drain into the axillary vein. However, there are some marked exceptions.
  - Veins accompanying branches of thoracoacromial artery drain into the cephalic vein, which, in turn enters the axillary vein.
  - The thoraco-epigastric veins which are formed by union of superficial veins of the inguinal region with tributaries of axillary vein also drain into the axillary vein.
- It is customary to describe three parts of the axillary vein corresponding to the three parts of the artery. But, owing to the direction of blood flow in the vein, the parts are reversely named. The commencement of the vein (distal part) is the third part; and the termination of the vein (proximal end) is the first part.
- The axillary vein has two or three bicuspid valves.

Clinical Correlation

- In many individuals, a connecting vein between the upper part of the cephalic vein (deltopectoral vein) and the external jugular vein (lying in the neck) runs across the clavicle. In case of injury to the axillary vein (or in surgical removal of a segment) this communication helps to maintain venous drainage of the upper limb. Fractures of clavicle may damage this communicating vein.
- The axillary vein is specifically vulnerable to injury when the arm is fully abducted. In this position, the vein overlaps the artery completely and is anteriorly shifted. Since it is also a large vein, it is liable to be damaged. Any wound in the axillary region can easily injure the vein too.
- Direct injury to the axillary vein is dangerous. Bleeding is profuse. There s the risk of air being sucked into the ve n producing air emboli.
- The part of the vein along the first part of axillary artery may be compressed by the subclavius muscle during abduction, especially, when the arm is held in prolonged abduction above the head, leading to axillary vein thrombosis.
- The apical, central and lateral groups of axillary nodes are very closely related to the axillary vein. Hence, surgical removal of these lymph nodes during mastectomy may cause accidental injury to the axillary vein leading to post operative thrombosis.

Axillary Lymph Nodes

Many lymph nodes are present embedded in the fibrofatty tissue of axilla. They are about 20–30 in number and drain lymphatics from (Fig. 13.13)
- Upper limb,
- Most of the mammary gland, and
- Cutaneous lymphatics from the trunk above the level of umbilicus.

The lymph nodes are classified into the five groups; the grouping reflects the pyramidal shape of the axilla.

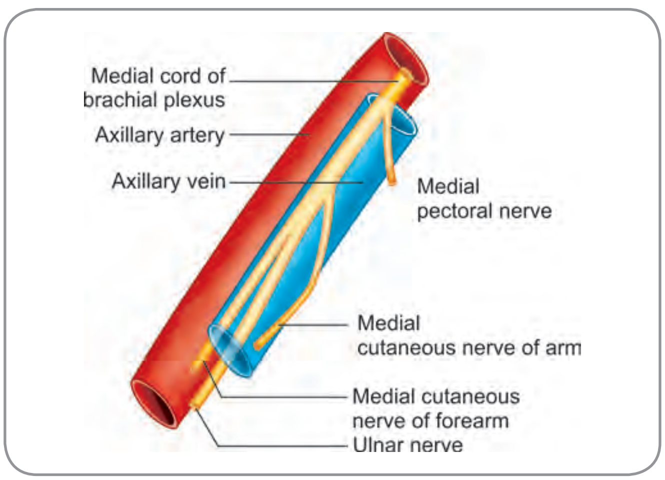


Fig. 13.12: Relations of the axillary vein

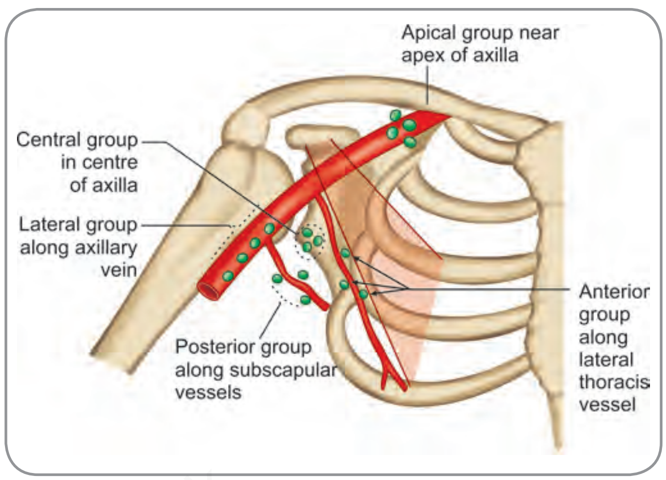


Fig. 13.13: Axillary lymph nodes seen from the front

1. The ***anterior (or pectoral) group*** of nodes (3 to 5 nodes): These are present closer to the anterior (pectoral) wall of axilla; they lie along the lower border of pectoralis minor and around the lateral thoracic vessels; they drain the anterior thoracic wall and thus receive most of the lymphatics from the breast.
2. The ***posterior (or subscapular) group*** of nodes (6 to 7 nodes): These lie along the posterior wall of axilla and the subscapular vessels over the subscapularis muscle; they receive afferents from the posterior thoracic wall and dorsal part of trunk up to the level of iliac crest.
3. The ***lateral (or humeral) group*** of nodes (4 to 6 nodes): These are located along the lateral wall of axilla along the axillary vein; they receive afferents from the entire upper limb except for the region drained by the cephalic vein.
4. The ***central group*** of nodes (3 to 5 large nodes): These lie near the base of axilla, deep to pectoralis minor, embedded in fat and in relation to the second part of axillary artery; they receive afferents from the anterior, posterior and the lateral group of axillary lymph nodes.
5. The ***apical group*** of nodes (4 to 6 large nodes): These lie near the apex of the axilla and hence the name; they lie along the axillary vein and the first part of axillary artery; they receive afferents from
   - Central group of lymph nodes and also from the other groups directly,
   - Upper part of breast and
   - Lymphatics from the region of upper limb drained by the cephalic vein

The efferents from the apical group traverse the cervicoaxillary canal and drain into the ***subclavian lymph trunk***.

Clinical Correlation

As the apical group drains the upper limb and major part of the breast, palpation of this group of nodes helps in the clinical assessment of the diseases affecting these regions especially nfection and malignancy. For palpation of the apical group, the fingers of one hand are pushed upwards from the base of the axilla towards its apex, while the fingers of the other hand are approached from above with the arm in relaxed position.

Cancer of the breast causes painless enlargement of lymph nodes whereas an infection of the lymph nodes leads to painful enlargement.

In malignancy of breast, axillary node clearance is undertaken along with the removal of breast depending on the stage of malignancy. The axilla is approached through its base for the lymph node clearance.

BRACHIAL PLEXUS AND ITS BRANCHES

The brachial plexus is formed by the union of ventral rami of the lower four cervical nerves and the greater part of the first thoracic nerve. The plexus formation allows for the nerve fibres from various spinal segments to be distributed to various parts of the upper limb efficiently and within restricted space (Fig. 13.14).

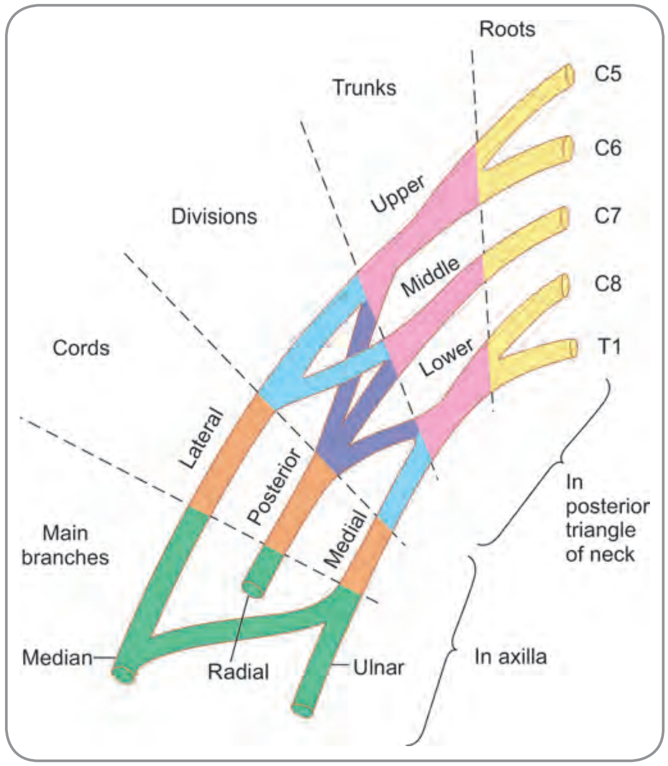


Fig. 13.14: Basic plan of the brachial plexus

Usually the brachial plexus is formed by the C5 to T1 roots with small contributions from C4 and T2. Sometimes the contribution from C4 is large, in which case the T1 root will be small and the contribution from T2 is absent. This is called the ***prefixed brachial plexus,*** because the plexus appears to be ***fixed*** one segment higher than normal. The reverse condition is one in which the plexus appears to be ***fixed*** one segment lower ,i.e., it is ***postfixed***. In this case, the contribution from C4 will be absent with a small C5 root and a large contribution from T2.

The entire brachial plexus is arranged as roots, trunks (and their divisions) and cords. The main branches arise as continuations of the cords; some branches also arise from other parts of the plexus.

Since the brachial plexus lies partly in the neck and partly in the axilla, it is described in two parts, namely—(1) the supraclavicular part and (2) the infraclavicular part. The plexus is formed in the posterior triangle of the neck and so the roots and trunks lie in this region. The cords and their branches lie in the axilla. To reach the axilla from the neck, the plexus passes through the ***cervicoaxillary canal,*** behind the medial part of the clavicle. In the axilla the cords and their main branches are closely related to the axillary artery.

Development

Motor nerve fibres are seen to be emerging out of the developing spinal cord as early as the fourth week of embryonic life. Soon after, dorsal root ganglia are formed from the neural crest cells; central processes from the ganglia grow into the spinal cord region; peripheral processes grow towards the motor fibres and unite with them to form a rudimentary spinal nerve. Almost immediately after this union, the spinal nerve divides into a ventral and a dorsal ramus. The spinal nerve and the rami are found on the medial aspect of the myotome of the segment/region. The dorsal ramus supplies the dorsal part of the myotome and the ventral ramus supplies the ventral part of the myotome. Once the limb bud arises, the ventral rami of the nerves of the spinal segments opposite the bud grow into the mesenchyme of the bud. Meanwhile successive ventral rami are connected by loops of nerve fibres; this leads to the formation of the brachial (lumbar in the case of the lower limb) plexus. The ventral rami give out anterior and posterior divisions. The anterior divisions supply the flexor muscles and the flexor surface; the posterior divisions supply the extensor muscles and the extensor surface.

Roots of Brachial Plexus

The ***roots*** of the plexus are the ventral rami of spinal nerves C5, C6, C7, C8 and T1, with contributions from C4 and T2.

Trunks of Brachial Plexus

- The roots from C5 and C6 join to form the ***upper trunk*** of the plexus at the lateral border of scalenus medius.
- The root from C7 continues as the ***middle trunk***.
- The roots from C8 and T1 join to form the ***lower trunk*** behind the scalenus anterior.

Divisions and Cords of Brachial Plexus

Each trunk divides into an ***anterior*** and a ***posterior division***. The anterior divisions of the upper and middle trunks join to form the ***lateral cord***. The anterior division of the lower trunk continues as the ***medial cord***. The posterior divisions of all the three trunks join to form the ***posterior cord.***

Relations of the Brachial Plexus

The roots enter the neck between the scalenus anterior and scalenus medius muscles. The trunks and divisions cross the posterior triangle and the cords reach the axilla. Along with the axillary artery and vein, the plexus gets enclosed in the axillary sheath in the axilla.

The cords of the plexus lie in the axilla and form specific relations to first and second parts the axillary artery.

- All the three cords are superior and lateral to the first part of the artery.
- The medial cord crosses behind the artery to reach the medial aspect of the second part.
- The posterior cord moves to reach posterior to the second part of he artery and the lateral cord lies on the lateral aspect

Therefore, the cords have such relationship to the second part of the artery which is indicated by their names (medial cord being medial, posterior cord being posterior and lateral cord being lateral). Several branches of the cords continue this relationship to the third part of the artery.

Branches of Brachial Plexus

Branches of the brachial plexus supply the entire upper limb. They also supply some structures in the neck.

They arise from the roots, the trunks and the cords. The branches arising from roots and trunks arise in the neck and are, therefore called ***supraclavicular branches*** (not to be confused with the supraclavicular nerves that are seen in the pectoral region).The branches from cords arise in the axilla and so, are called ***infraclavicular branches***.

Branches Arising from Roots (Fig. 13.15)

- Each root of the plexus gives branches to some muscles lying in the neck (scalene muscles and longus colli).
- Root C5 gives a contribution to the ***phrenic nerve***. The phrenic nerve descends into the thorax to supply the diaphragm.
- The ***dorsal scapular nerve*** arises from root C5.
- The ***long thoracic nerve of Bell*** (Fig. 13.16) is the nerve to serratus anterior. It arises from roots C5, C6 and C7. The nerve runs downwards first in the neck over the scalene muscles; then on the medial wall of the axilla over the serratus anterior. It reaches up to the lower border of the serratus anterior and gives separate twigs to its digitations.

Branches Arising from Trunks

Only the upper trunk gives branches. They are:

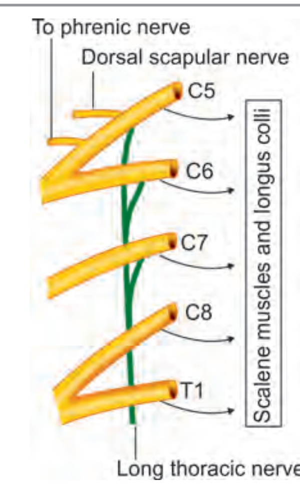


Fig. 13.15: Branches arising from the roots of the brachial plexus

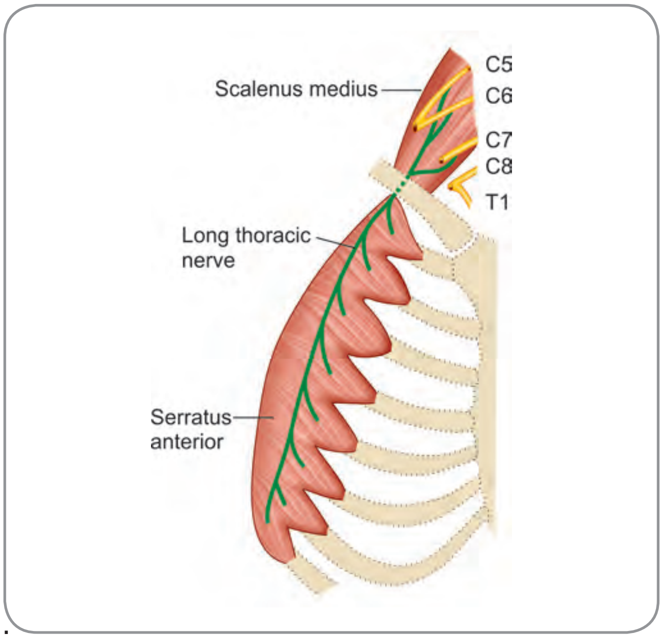


Fig. 13.16: Course of the long thoracic nerve

- Nerve to subclavius and
- Suprascapular nerve.

The ***nerve to subclavius*** descends in front of the brachial plexus and the third part of the subclavian artery. It passes behind the clavicle to reach the deep surface of the subclavius that it supplies.

The ***suprascapular nerve*** runs laterally and backwards over the shoulder to reach the suprascapular notch in the scapula. It supplies the supraspinatus muscle and sends articular rami to the shoulder and the acromioclavicular joints.

Branches from Cords

Branches of the lateral cord are:

- The lateral pectoral nerve (C5,C6,C7);
- Lateral root of median nerve (C5,C6,C7);
- Musculocutaneous nerve (C5,C6,C7)

The ***lateral pectoral nerve*** (Fig. 13.16) is the main nerve supplying the pectoralis major. It also gives some fibres to the pectoralis minor through a communication with the medial pectoral nerve. After its origin from the lateral cord, the nerve runs medially across the axillary artery. It then pierces the clavipectoral fascia to enter the pectoralis major.

The ***lateral root of median nerve*** is a continuation of the lateral cord and lies lateral to the third part of the axillary artery. It joins together with the medial root of median nerve from the medial cord in front of the third part of axillary artery and then descends on the lateral side of the axillary artery into the arm, forearm and hand (the median nerve does not give any branch in the axilla).

The ***musculocutaneous nerve,*** arising from the lateral cord, passes laterally to enter the coracobrachialis muscle and supply it It then pierces the muscle and leaves the axilla. Subsequently, it descends into the arm, where it gives branches to biceps brachii and brachialis. The nerve then pierces the deep fascia and becomes the lateral cutaneous nerve of forearm, which descends along the lateral border of forearm to supply twigs to skin.

Branches of the Medial cord are:

- Medial pectoral nerve (C8,T1);
- Medial root of median nerve (C8,T1);
- Medial cutaneous nerve of arm (C8,T1);
- Medial cutaneous nerve of forearm (C8,T1);
- Ulnar nerve (C7,C8,T1).

The ***medial pectoral nerve*** is the main nerve of supply for the pectoralis minor. It also sends a few fibres to the pectoralis major. At its origin from the medial cord the nerve lies behind the axillary artery. Passing medially and forward it emerges from behind the artery and enters the pectoralis minor. Some branches pass through this muscle to reach the pectoralis major (Fig. 13.17).

The ***medial root of median nerve*** joins the lateral root of median nerve in front of the third part of the axillary artery to form the median nerve which then descends into the arm, forearm and hand.

The ***medial cutaneous nerve of the arm*** runs downwards first on the medial side of the axillary vein and then enters the arm lying on the medial side of the basilic vein. It receives a communication from the intercostobrachial nerve and supplies skin on the medial side of arm.

The ***medial cutaneous nerve of the forearm*** runs downwards on the medial side of the axillary artery (between it and the axillary vein, superficial to the ulnar nerve) and then enters the arm on the medial side of the brachial artery.

The ***ulnar nerve*** is the main continuation of the medial cord. In the axilla, the nerve lies medial to the third part of the axillary artery (between it and the axillary vein, deep to

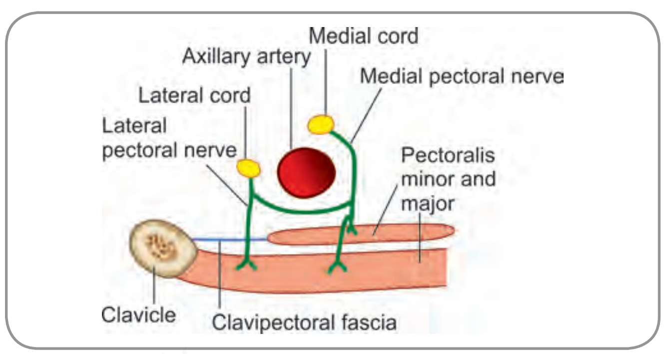


Fig 13.17: Course of the pectoral nerves

the medial cutaneous nerve of forearm). It then enters the arm, the forearm and the hand.

Branches of the Posterior cord are:

- Upper subscapular nerve (C5, C6);
- Lower subscapular nerve (C5, C6);
- Nerve to latissimus dorsi (thoracodorsal nerve) (C6, C7, C8);
- Axillary nerve (C5,C6);
- Radial nerve (C5-8,T1).

The ***upper subscapular nerve*** supplies the subscapularis at a higher level (Fig. 13.18).

The ***lower subscapular nerve*** supplies the teres major and also gives a branch to the subscapularis (Fig. 13.18).

The ***thoracodorsal nerve*** arises from the posterior cord between the subscapular nerves and is also called the nerve to latissimus dorsi. It passes downwards on the subscapularis along with the thoracodorsal artery to reach the anterior (or deep) surface of the latissimus dorsi to supply it.

The ***axillary nerve,*** being one of the terminal branches of the posterior cord, is at first lateral to radial nerve and posterior to axillary artery**.** At the lower border of subscapularis, it turns backward to enter the quadrangular space along with the posterior circumflex humeral vessels. As it passes through the space, it is in close relation to the inferior aspect of the shoulder joint and gives out an articular branch. It is also closely related to the medial surface of surgical neck of humerus at this level. Having passed through the space, the nerve divides into anterior and posterior divisions. The anterior division (or the anterior terminal branch) winds around the surgical neck of humerus under cover of the deltoid muscle; it suppl es the muscle itself and also the skin over the lower part of the muscle. The posterior division (or the posterior terminal branch) gives muscular branches to teres minor and deltoid. It then emerges from the posterior border of deltoid to the subcutaneous area, to become the upper lateral cutaneous nerve of arm.

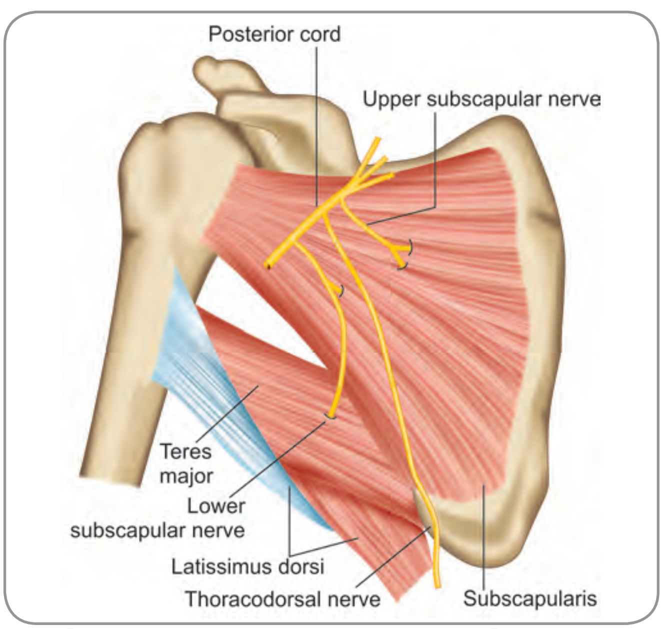


Fig. 13 18: Course of upper and lower subscapular nerves, and of the thoracodorsal nerve

The ***radial nerve*** is the main continuation of the posterior cord and the largest branch of the plexus itself. In the axilla, it lies posterior to the third part of the axillary artery. It then enters the arm through the lower triangular space along with the profunda brachii vessels, the forearm and the hand.

Added Information

- The nerve to subclavius, through its C5 fibres may give a contribution to the phrenic nerve. If such a contribution is present, it is called an accessory phrenic nerve.
- The brachial plexus can itself be described as a plexus that has alternate union and division of nerves. Five anterior primary rami unite; three trunks thus formed divide; six divisions so formed unite; three cords then formed bifurcate; five terminal branches (Ulnar, median, musculocutaneous, axillary and radial) result
- The nerve to serratus anterior takes origin from roots of the plexus; since it is developmentally a posterior muscle, the nerve descends behind the axillary vessels.

Clinical Correlation

Applied anatomy of the brachial plexus and its branches

The brachial plexus or its branches may be affected by injury or by disease. Injury may be direct ,e.g., by stabs or gun shots; or indirect through fractured bones, stretching of the neck, etc. Symptoms in the area supplied by the plexus may also be produced by injury or disease of the spinal cord in the segments concerned. In such cases, it is important to determine the exact segments of the cord which are affected; this can be done either by testing the muscles and finding out which are paralysed or by mapping out areas of skin in which sensations are lost or diminished. Therefore, it is necessary to know the nerve supply of both muscles and skin, segment wise (or root wise), rather than nerve wise.

Injury to a motor nerve results in ***paralysis*** of the muscle(s) supplied by it. This is manifested in two ways:

- The patient is unable to perform movements dependent on the muscle(s) concerned.
- Normal posture of a limb, or part of a limb, is disturbed. Posture depends on the balance between tone of opposing muscles. For example, the resting forearm is in the semi prone position because of the balance between tone of the supinators and the pronators. If the supinators are paralysed, the unopposed tone of the pronators leads to pronation of the forearm. Such

effects account for the characteristic deformities which are associated with injury to different nerves.

The following are some of the common conditions in which paralysis occurs due to injury / disease specific to certain nerves or points.

Erb's Point and Erb's Paralysis

The region where C5 and C6 roots of the brachial plexus join to form the upper trunk is often referred to as the ***Erb's point*** (Fig. 13.19). Six nerves meet at this point. (See Fig. 12.10 Chapter 12) These nerves are:

- Roots C5 and C6,
- Anterior and posterior divisions of the upper trunk,
- Suprascapular nerve and
- Nerve to subclavius.

Injury at this point produces a syndrome that is referred to as ***Erb's paralysis*** (or as ***Erb-Duchenne palsy*** or as ***upper lesion of brachial plexus***). Any injury that forcibly stretches the region of the upper trunk of the brachial plexus can cause this paralysis. Such injuries occur when there is a fall on the side of head or when there is undue pull upon the neck; example of the latter is birth injury that happens especially during the delivery of an aftercoming head in breech delivery.

Erb's palsy results in paralysis of muscles supplied by nerves C5 and C6 which are:

- The deltoid,
- The biceps brachii,
- The brachialis,
- The coracobrachialis,
- The subclavius,
- The supraspinatus,
- The infraspinatus,
- The brachioradialis and
- The supinator.

Features of Erb's palsy are as follows:

- The arm cannot be abducted due to paralysis of deltoid and of supraspinatus; it hangs by the side of the body;
- Unopposed medial rotation of the arm due to paralysis of infraspinatus (a lateral rotator);
- The forearm cannot be flexed due to paralysis of biceps brachii and of brachialis (flexors of forearm); it remains extended;
- The forearm remains pronated, due to paralysis of biceps and of supinator (both supinators);
- Combination of medial rotation of the arm and pronation of the forearm makes the palm face backwards, giving the position a fond nickname as ***waiter's tip position*** (Fig. 13.20) (appears like a waiter or a porter hinting for a tip);
- Sensory loss, if present, is seen along the outer aspect of arm.

Klumpke's Paralysis

Klumpke's paralysis (or lower lesions of brachial plexus) is caused by injury to roots C8 and T1, or to the lower trunk of the brachial plexus. The injury may be caused by traction injuries due to hyperabduction of the arm that occurs when a person falls from a height and tries to hang to an object. The first thoracic nerve is torn and since its fibres run in the median and ulnar nerves, all the small muscles of the hand are affected.

The flexors of the wrist and all the small muscles of the hand are paralysed. Paralysis of the flexors of the wrist leads to extension of the wrist joint and paralysis of the interossei causes extension at the metacarpo phalangeal joints (due to unopposed action of the extensor digitorum muscles) and flexion at the interphalangeal joints (due to

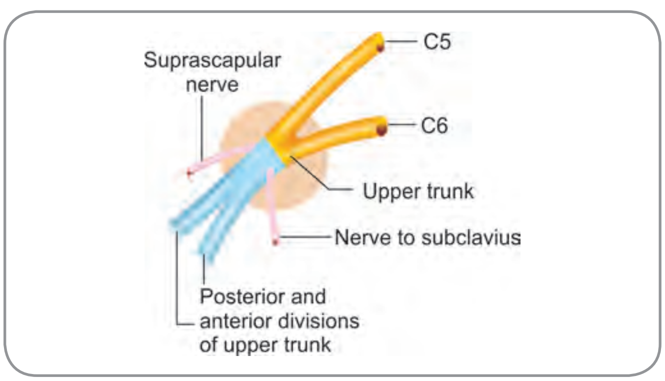


Fig. 13.19: Nerves meeting at Erb's point

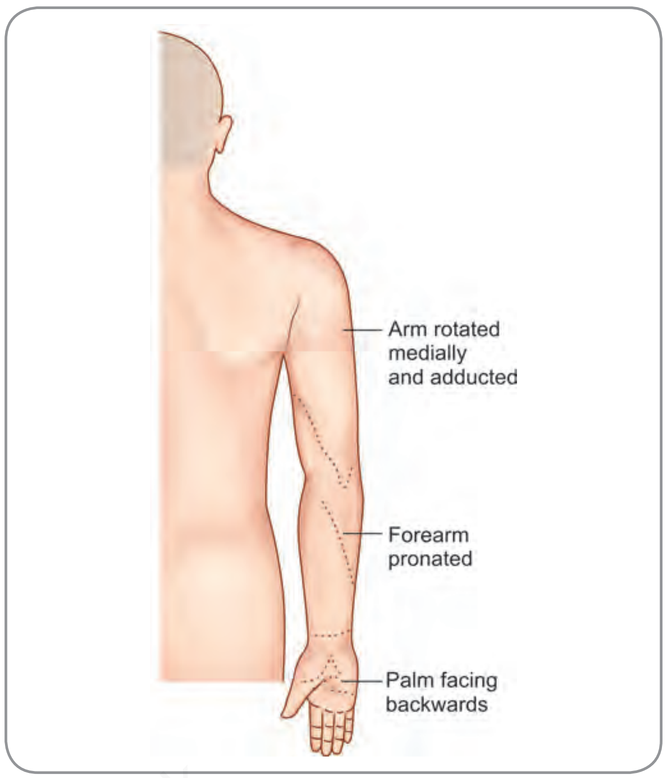


Fig. 13.20: Waiter's tip position of upper limb in Erb's paralysis

unopposed action of the flexor digitorum superficialis and profundus muscles). This gives rise to a deformity known as ***claw hand*** (fingers go into a clawed appearance). Sensory loss may be present along the medial border of forearm and hand. In addition to these symptoms, autonomic disturbances occur due to the involvement of the sympathetic fibres supplying the head and neck, which pass through the T1 segment to reach the inferior cervical ganglion. Such autonomic disturbances cause ***Horner's syndrome***; the signs and symptoms of Horner's syndrome are constriction of pupil, drooping of the upper eye lid, enophthalmus and absence of sweating of face and head.

Cervico-axillary canal and Scalenus Anterior Syndrome

As already mentioned, the cords of brachial plexus pass from the neck to the axilla through its apex, which otherwise is called the cervico-axillary canal. The subclavian artery also continues as the axillary artery at this level.

Usually, the T1 root to the brachial plexus curves over the first rib (medial boundary of the cervico-axillary canal) to join the root from C8. In normal persons this does not cause any problem. However, when the shoulders begin to sag with age, or in persons who have to lift heavy weights, rubbing of the nerve trunk on the rib may be sufficient to cause symptoms. Similar symptoms can also be produced by pressure of a large or hypertrophied scalenus anterior muscle on the lower trunk (scalenus anterior/anticus syndrome or scalene syndrome). Structures passing through the cervico-axillary canal are compressed leading to neurological and vascular symptoms. Neurological symptoms are those of compression of the lower trunk and resemble those of Klumpke's paralysis. Pain radiating to the medial side of the arm is a conspicuous feature because of irritation of the trunk due to rubbing against the first rib.

Cervical Rib

Occasionally, a rudimentary rib called ***cervical rib*** may be present in relation to the seventh cervical vertebra. The anterior part of the rib may be represented by a fibrous cord. When such a cervical rib is present, T1 root has to curve over this rib (or over the fibrous band) which results in considerably greater pressure on the nerve root as compared to that from a normal first rib. The same symptoms as described above (in scalenus anterior syndrome) occur with greater intensity and at an earlier age. However, a cervical rib may exist without producing any symptoms, especially in the young. Similarly, the symptoms associated with a cervical rib can be present in the absence of such a rib if the brachial plexus is postfixed (wherein the T2 root has to curve over the normal first rib).

Injury to Long Thoracic Nerve

The long thoracic nerve (which supplies the serratus anterior) can be injured in persons who carry heavy weight on the shoulders. It can also be injured by blows on the posterior triangle of neck or during a radical mastectomy procedure. Normally, the serratus anterior (along with the trapezius) helps in overhead abduction of the arm by rotating the scapula forwards. This movement is not possible when the nerve is injured

The serratus anterior can be tested by asking the patient to stretch his upper limbs forwards, place his palms against a wall and push them against it. When the muscle is paralysed the medial margin of the scapula projects backwards which is called ***winging of the scapula***.

Injuries to Other Nerves

Injuries to other individual nerves of the brachial plexus may happen due to various causes. The posterior cord, the axillary nerve and the radial nerve can be damaged by the pressure of a crutch when the latter is being pressed upwards in the armpit. A drunken man falling asleep with one arm over the back of a chair can sustain damage to the radial nerve; since in olden times, such occasions were regular after a Saturday night's party, the condition itself came to be referred as ***Saturday night palsy***. Fractures and dislocations of upper end of humerus may damage both the axillary and radial nerves at the axillary level.

Brachial Plexus Block

Injection of local anaesthetic into the axillary sheath blocks all the branches of the brachial plexus. Operations can then be performed on the upper limb.

Tendon Reflexes

In examining the nervous system, use is often made of ***tendon reflexes*** which can help to localise segmental levels of lesions.

- The ***biceps tendon reflex*** is elicited by tapping the biceps tendon This leads to flexion of the elbow. A positive reflex confirms integrity of segment C5 (and partly of C6)
- Similarly the ***triceps tendon reflex*** is elicited by a tap on the triceps tendon—it causes extension of the elbow and confirms integrity of segment C7 (and partly of C6 and C8).
- The ***brachioradialis tendon reflex*** (also sometimes called ***supinator jerk***) is elicited by a tap over the insertion of the brachioradialis. This normally causes supination of the forearm, and confirms integrity of segment C6 (and partly C5 and C7).

Multiple Choice Questions

1. What is false about axillary artery:
   a. It is a continuation of subclavian artery
   b. It is crossed by pectoralis minor
   c. It is accompanied by axillary vein only in its distal third
   d. It gives out the superior thoracic artery from its first part

2. The axillary vein:
   a. Receives the thoraco-epigastric veins
   b. Is medial to the medial cutaneous nerve of arm
   c. Has no valves
   d. Is prone to injury when arm is in adduction

3. The humeral group of axillary lymph nodes:
   a. Receive lymph from entire upper limb
   b. Receive lymph from the distal part of upper limb and posterior thoracic wall
   c. Receive lymph from entire upper limb except for region drained by cephalic vein
   d. Receive lymph from entire upper limb and mammary gland

4. The long thoracic nerve of Bell:
   a. Supplies serratus anterior
   b. Arises from C5 root only
   c. Runs on the posterior wall of axilla
   d. Descends in front of the axillary vessels

5. The resting position of semipronation is due to:
   a. Unopposed tone of pronators
   b. Balance between pronators and supinators
   c. Inertia in the supinator muscle
   d. Continuous impulses in brachioradialis

ANSWERS

1. c **2.** a **3.** c **4.** a **5.** b

Clinical Problem-solving

Case Study 1: A 35-year-old man complains of pain radiating down the medial side of his right upper limb. The pain is of recent onset.

- What bony abnormality, if present, can cause such a symptom? Reason out.
- If there is no abnormality, what other causes would you think of?
- Correlate the anatomical reason for all the above mentioned possibilities.

Case Study 2: A physician, on examination of a patient, finds out that the lateral group of axillary lymph nodes is enlarged.

- Which area should the physician search for the primary cause for lymphadenitis?
- Where do the afferents to this group come from and where do the efferents go to?
- What are the other groups of nodes and when would they be involved?

(For solutions see Appendix).

Chapter 14

The Back and Scapular Region

Frequently Asked Questions

- Discuss the role of scapula in the movements of upper limb.
- Write notes on: (a) Trapezius, (b) Latissimus dorsi, (c) Rhomboideus muscles
- Write notes on the posterior axioappendicular muscles
- Discuss the deltoid muscle with regard to its attachments, relations, nerve supply, actions and functional significance. Add a note on its applied anatomy.
- Write in detail the role of supraspinatus-deltoid complex in the abduction of arm.
- Discuss the rotator cuff muscles.
- Write notes on: (a) Subscapularis, (b) Supraspinatus, (c) Quadrangular space, (d) Axillary nerve, (e) Suprascapular artery, (f) Anastomoses around the scapula.

THE BACK

The region comprising the posterior aspect of the thorax and abdomen is referred to as the ***back***. Three layers of muscles (called the extrinsic back muscles) are found in this region. The deepest layer belongs to the back proper (and is studied along with the head and neck). Superficial to this layer, are two other layers (superficial and intermediate groups) of muscles which belong to the upper limb, but are placed on the back for functional reasons. Some of these are inserted into the scapula while others reach the humerus.

The muscles of the upper limb present on the back and in the shoulder region produce important movements of the upper limb. To understand their actions properly, it is necessary to understand some facts about these movements before we study the muscles. The movements of the upper limb can primarily be grouped into two categories—a. movements of the arm at the shoulder joint (glenohumeral joint) and b. movements of scapula at the sternoclavicular and the acromioclavicular joints put together. Though these movements are classified into two categories (for the sake of descriptive convenience), both are interdependent; contribution from the glenohumeral joint is present in the movements of scapula and vice versa.

MOVEMENTS OF ARM

Movements of the arm take place at the shoulder joint which is formed by the articulation of the head of humerus with the glenoid cavity of scapula. Basic movements at a multiaxial joint will be flexion, extension, adduction, abduction, and rotation. However, in the case of the arm (and the glenohumeral joint), these movements are slightly different than at other joints.

The movements of the arm are described with reference to the plane of the scapula (and not to the trunk). In relation to the wall of the thorax, the scapula is placed obliquely so that its costal surface faces ***forwards*** and ***medially***, while the dorsal surface faces ***backwards*** and ***laterally***. Because of this orientation, the glenoid cavity does not face directly laterally, but faces ***forwards*** and ***laterally***.

Placement and orientation of the scapula preclude the following:

- In the neutral position the arm hangs vertically by the side of the trunk. Flexion and extension take place in a plane ***at right angles to the plane of the scapula***. In ***flexion,*** the arm moves forwards (Fig. 14.1) and ***somewhat medially***. Reversal of this movement (i.e., bringing it back to the side of the trunk) is ***extension***. Continuation of extension beyond the vertical position of the arm is called ***hyperextension***.
- Movements of abduction and adduction take place ***in the plane of the scapula*** In abduction, the arm moves laterally and somewhat forwards (Fig. 14.2). After reaching the horizontal position (i.e., from 1 to 2 in Fig. 14.2) the movement can be continued to raise the

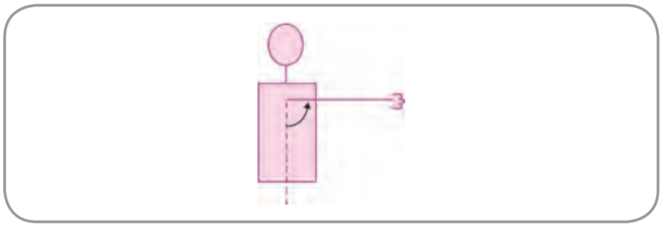


Fig. 14.1: Scheme to illustrate the movement of flexion of the arm

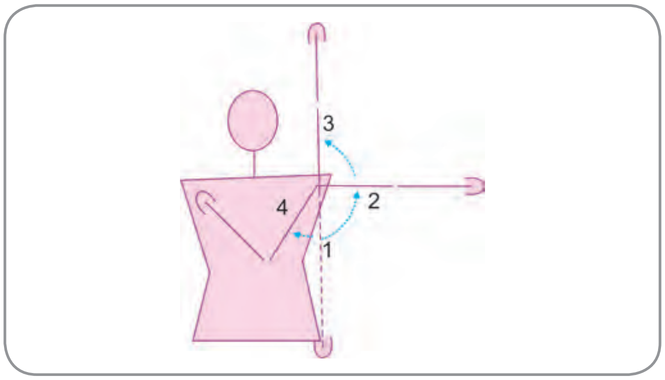


Fig. 14.2: Scheme to illustrate abduction and adduction of the arm

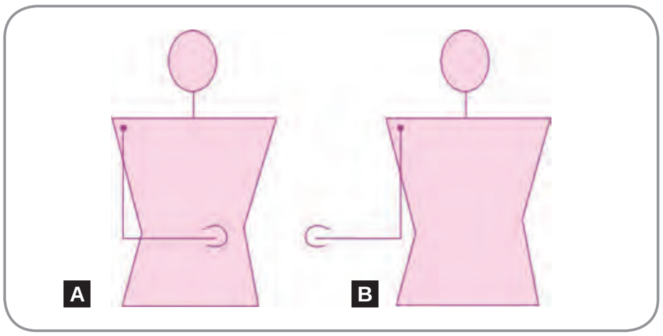


Fig. 14.3: **A.** Medial rotation of the arm and **B.** Lateral rotation of the arm

arm to a vertical position; this is referred to as ***overhead abduction***. Bringing the arm back to the neutral position is called ***adduction***. Further adduction brings the arm to the front of chest. Abduction and adduction take place partly at the shoulder joint and partly by the rotation of the scapula.

- The rotatory movements of the arm are ***medial rotation*** and ***lateral rotation*** (Fig. 14.3) and are named with reference to the front of the humerus. Rotation can be better understood if the forearm is flexed and the humerus studied. Rotation of the humerus that carries the flexed forearm medially is medial rotation The opposite movement in which the forearm is carried laterally is lateral rotation. It follows that any muscle passing from the trunk (or scapula) to the front of humerus will be a medial rotator. A muscle passing to the back of humerus will be a lateral rotator.

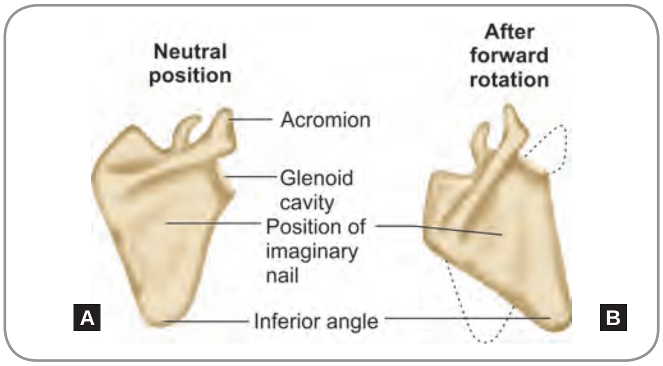


Fig. 14.4: **A.** Neutral position of the scapula and **B.** Position of the scapula after forward rotation

MOVEMENTS OF SCAPULA

Movements of the scapula occur at the sternoclavicular and the acromioclavicular joints together with some contribution from the glenoid joint However, it is a functional joint that contributes the maximum to scapular movements; this is the scapulothoracic joint where the two constituents of the joint are the scapula and the thoracic wall; the constituents are not connected by a joint capsule or ligaments as would be seen in any other joint; but they are kept together by muscles which help the scapula move over the thoracic wall. Various movements of scapula are:

- ***Protraction:*** The entire scapula slides forwards over the chest wall. Reversal of this movement is ***retraction***.
- ***Elevation:*** The entire scapula moves upwards (as in shrugging the shoulders); and the opposite movement is ***depression***.

In addition to these simple movements the scapula can undergo rotation. To understand this movement, imagine that the scapula is transfixed by an imaginary nail passing through the centre of its body (Fig. 14.4). Rotation is named in terms of movement of the inferior angle of the scapula. In ***forward rotation*** (also called ***lateral rotation***), the inferior angle of the scapula passes forwards and somewhat laterally. Simultaneously, the superior angle and the acromion pass backwards and medially. The glenoid cavity comes to face upwards. This movement takes place during abduction of the arm, and is essential for raising the arm above the head. Reversal of this movement constitutes the ***backward (or medial) rotation***.

MUSCLES OF THE BACK

The muscles of the back (as already noted) are arranged in three layers. The deepest layer (otherwise called the intrinsic back muscles or the deep back muscles) belongs both structurally and functionally to the back (and hence studied along with structures of head and neck). The intermediate and superficial layers together constitute the

Table 14.1: Trapezius	
Origin	• Medial one-third of superior nuchal line • External occipital protuberance • Ligamentum nuchae • Spines of vertebrae C7 to T12 • Intervening supraspinous ligaments
Insertion	• Posterior border of lateral one-third of clavicle • Medial margin of acromion • Upper border of crest of spine of scapula and the tubercle on it
Nerve supply	• Spinal part of accessory nerve (motor) • Branches from nerves C3, 4 (sensory)
Action	• Forward rotation of scapula (with serratus anterior) • Elevation of scapula (with levator scapulae) • Retraction of scapula (with rhomboids) • Draws the head of scapula backwards and laterally. When muscles of both sides act the head is drawn directly backwards

extrinsic back muscles. They connect the axial skeleton (trunk) to the appendicular skeleton (upper limb) and are placed on the posterior aspect of the body; hence they are called the posterior axioappendicular muscles. Since they act on the shoulder but are structurally away, they are also called extrinsic shoulder muscles.

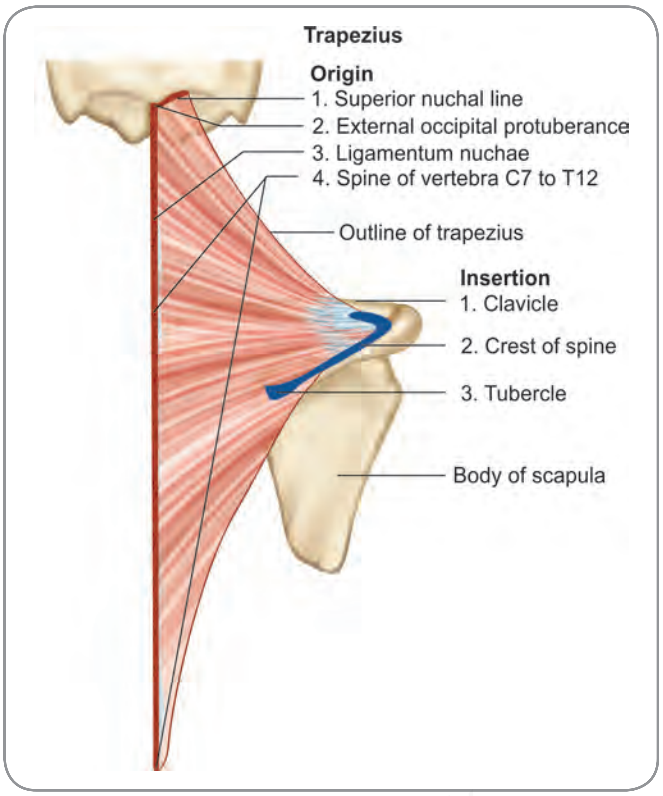


Fig. 14.5: Scheme to show the attachments of trapezius

The posterior axioappendicular muscles are in two layers:

1. Superficial posterior axioappendicular muscles—trapezius and latissimus dorsi (the muscles of the superficial most layer). The trapezius is described in Table 14.1 and Fig. 14.5. The latissimus dorsi is described in Table 14.2 and Fig. 14.6.
2. Deep posterior axioappendicular muscles—levator scapulae, rhomboideus minor and rhomboideus major (the muscles of the intermediate layer). These muscles are described in Table 14.3 and the attachments of the levator scapulae are shown in Fig. 14.7.

Table 14.2: Latissimus dorsi	
Origin	• Spines of vertebrae T7 to T12 • Intervening supraspinous ligaments • Thoracolumbar fascia • A slip from posterior part of the iliac crest • Few slips from the lowest 3 or 4 ribs • A slip from the inferior angle of scapula
Insertion	The muscle ends as a tendon which is inserted into anterior aspect of upper end of humerus, in the floor of intertubercular sulcus
Nerve supply	Thoracodorsal nerve (C6, 7, 8) otherwise called nerve to latissimus dorsi, a branch of poster or cord of brachial plexus
Action	• Adduction and medial rotation of arm • Extension of flexed arm, against resistance • Depression of raised arm against resistance (with pectoralis major) • Elevation of trunk (when the arms are raised and fixed) (with pectoralis major)
Notes	Fibres of the muscle converge towards axilla and end in a tendon that winds round the lower border of the teres major The two together form the posterior fold of the axilla (posterior axillary fold)

Dissection

Place the cadaver in the prone position. It is better to perform the ensuing dissection in coordination with those dissecting the back region. Skin incisions should be made to preserve and permit study of the various structures of the region. Make a vertical incision from the external occipital protuberance on the posterior midline of the body. The inferior limit of the incision, if possible, should extend to the level of the inferior angle of scapula. Make a transverse incision from the inferior limit of the vertical incision to the lateral aspect of the trunk. Make another transverse incision, from the vertical incision to the lateral curve of the shoulder, superior to the scapula and acromion. Make a transverse incision from the external occipital protuberance to the base of mastoid. One or two transverse incisions parallel to the transverse incisions already mentioned may be made so as to help reflection of skin. Reflect skin flaps laterally Try to identify the vessels and nerves n

contd...

Dissection *contd...*

the superficial fascia. This may not be completely possible if the student is comparatively new to dissection and is in the initial phases of anatomical study. Reflect the superficial and deep fascia along the lines of skin reflection (take the help of a senior colleague or facilitator during all these steps).

Identify the trapezius muscle; clean the fascia and fat over its surface. Look out for the borders of the muscle; clean its inferolateral border. Insert your fingers underneath the muscle and try to separate it from deeper muscles. With the space and protection provided by your fingers, cut the trapezius from its medial attachment (start working up from the inferior point). Gradually separating the muscle from its underlying structures, reflect the muscle laterally. While working so it is necessary to be careful about the accessory nerve, greater occipital nerve and associated plexus of nerve twigs The facilitator should help you preserve these.

With the cadaver in the prone position and with the exposure rendered by the wide incisions, it is preferable to study the other muscles of the back. The latissimus dorsi can now be located, cleaned and defined. Once the trapezius has been reflected, the rhomboidei muscles are exposed. The surfaces and borders of these muscles should be cleaned and defined. The two muscles may not be well separated. If it can be permitted, the rhomboids may be reflected. Inserting your fingers underneath the rhomboideus major from its inferior border, slowly cut the lateral attachments of both the muscles and reflect them laterally. The dorsal scapular nerve and vessels can be seen on the deeper aspect of the rhomboids close to their lateral attachments.

The levator scapulae muscle can now be identified. The inferior attachment of this muscle should be located. The dorsal scapular nerve and artery can be traced upwards from where they were located near the rhomboids. It can be seen that these structures pass deep to the levator scapulae.

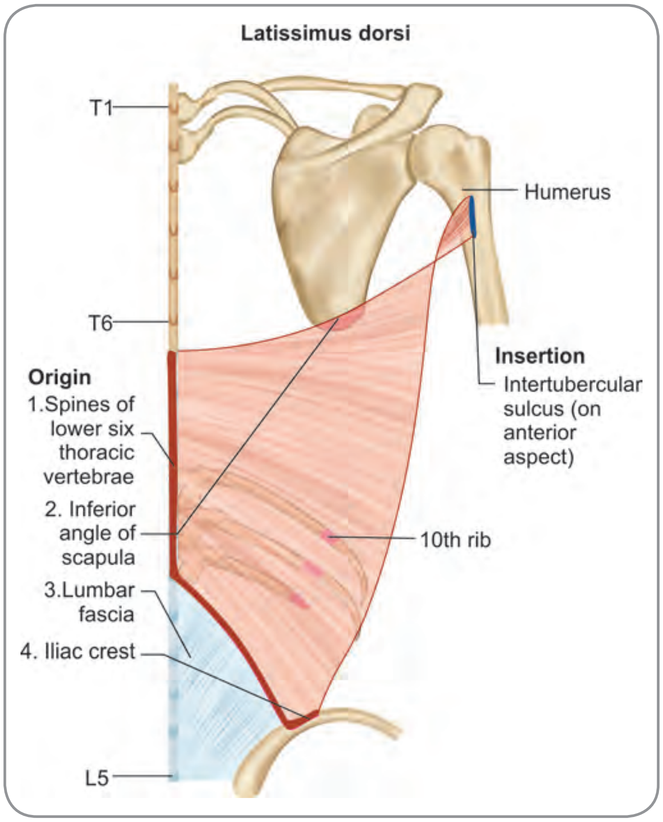


Fig. 14.6: Scheme to show the attachments of latissimus dorsi

Additional Notes on the Posterior Axioappendicular Muscles

- Trapezius provides direct attachment of the pectoral girdle to the trunk. It is a flat, triangular muscle that extends over the back of neck and upper thorax. The muscles of both sides together form a diamond-shape, from which the muscle derived its name (Greek. Trapezium=four sided irregular figure). The muscle assists in suspending the upper limb from the thorax. The fibres of trapezius can be divided into three groups; each group has a different action on the scapulothoracic joint. Superior descending fibres elevate the scapula; middle horizontal fibres pull the scapula posteriorly; inferior ascending fibres depress the scapula. The ascending and descending fibres act in harmony to rotate the scapula. The middle fibres of the two muscles act together to draw the scapulae posteriorly.

Table 14.3: Levator scapulae, rhomboideus minor and rhomboideus major

Muscle	Levator scapulae	Rhomboideus minor	Rhomboideus major
Origin	Transverse processes of upper four cervical vertebrae	• Lowest part of ligamentum nuchae • Spines of vertebrae C7 and T1	• Spines of vertebrae T2 to T5 • Intervening supraspinous ligaments
Insertion	Medial border of scapula from superior angle to root of spine	Medial border of scapula opposite root of spine	Medial border of scapula, from root of spine up to inferior angle
Nerve supply	• Branches from spinal nerves C3, C4. Dorsal scapular nerve (C5)	Dorsal scapular nerve (C5)	Dorsal scapular nerve (C5)
Action	• Elevation of scapula • Backward rotation of scapula • Stabilisation of scapula during movements of upper limb • Bends neck to its own side	• Retraction of scapula • Backward rotation of scapula • Stabilisation of scapula during movements of upper limb	• Retraction of scapula • Backward rotation of scapula • Stabilisation of scapula during movements of upper limb

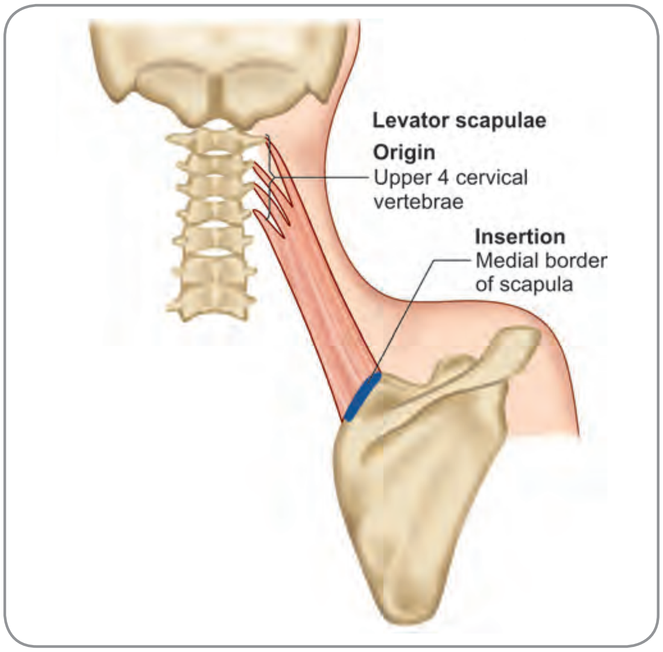


Fig. 14.7: Attachments of levator scapulae

- Latissimus dorsi (Latin. Latissime=wide; dorsi=back; the widest muscle of the back) is a large, fan-shaped muscle that covers a wide area on the back. It acts directly on the glenohumeral joint and indirectly on the scapulothoracic joint. It extends the arm; rotates it medially. It helps in movements where the arm is drawn behind the head. Acting in unison with the pectoralis major, it produces adduction of the humerus and helps raising the trunk to the arm. Hence, it plays a major role in swimming, paddling boats, climbing trees, raising the body when one hangs from a horizontal bar and while pushing one's way through a crowd.

Dissection

With the cadaver in the prone position, abduct the arm to about 45 degrees. Place a rectangular block under the chest.

Reflect the trapezius muscle, preferably superiorly or superomedially. If the skin incisions had stopped at the level of the acromion, they should be appropriately extended to expose the upper arm.

Clean the surfaces and borders of the deltoid muscle. The muscle is now slowly and gradually detached from its proximal attachments and then reflected laterally. The axillary nerve and the posterior circumflex humeral vessels are located on the deeper aspect of the muscle; they are defined and traced around the surgical neck of humerus.

The axillary nerve and posterior circumflex vessels are subsequently followed to the quadrangular space. The space is defined and studied.

Look out for the long head of triceps brachii muscle. Locate the teres major and minor muscles. After defining these muscles, study the triangular space.

Now, identify the supraspinatus and infraspinatus muscles. Using blunt dissection, both the muscles can be transected and their portions reflected medially and laterally. The suprascapular artery and nerve should be located deep to these muscles and studied. Traced superiorly, the artery can be seen to pass over the superior transverse scapular ligament and the nerve under the ligament. Traced inferiorly, the artery will be seen to join the anastomosis around the scapula.

- The deep posterior axioappendicular muscles are otherwise called the axio-scapular or thoraco-appendicular muscles. They connect the appendicular skeleton to the axial skeleton
- The superior part of levator scapulae (Latin levare=to raise, to elevate) lies under cover of sternocleidomastoid; inferior part lies under cover of trapezius. Acting along with trapezius, the levator elevates and fixes the scapula. Acting along with the rhomboids, it rotates the scapula in such a way that the glenoid faces inferolaterally. When the levators of both sides act, the neck is extended.
- The rhomboids are named after their shapes (Greek. Rhombus=kite; shaped like a kite or a diamond).

NERVES OF THE BACK

Cutaneous Nerves of the Back

The skin of the back except the lateral part is supplied mainly by cutaneous branches arising from the dorsal rami of spinal nerves (Fig. 14.8). The lateral parts of the back are innervated by cutaneous branches from ventral rami.

- The dorsal ramus of each spinal nerve divides into medial and lateral branches. These branches supply the deep muscles of the back (erector spinae). (No muscle of either the upper or lower limb is innervated by dorsal rami). Of the two branches of a dorsal ramus, only one, depending on the region, gives off cutaneous branches.

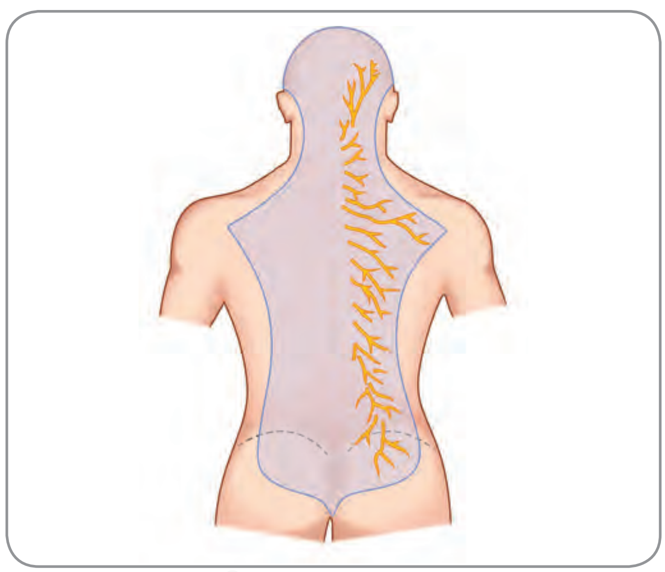


Fig. 14.8: Area of skin of the back supplied by dorsal rami of spinal nerves

In the cervical and upper thoracic regions, the cutaneous twigs are given out by the medial branches, and become superficial near the middle line of the back. In the lower thoracic and lumbar regions, cutaneous twigs arise from the lateral branch and become superficial along a line corresponding to the lateral edge of the erector spinae.

- Cutaneous branches innervating the lateral parts are the lateral branches of the intercostal nerves.

Nerves Supplying Muscles

Spinal Part of Accessory Nerve

The accessory nerve is the eleventh cranial nerve. It has a cranial part arising from the medulla oblongata of the brain and a spinal part arising from the upper part of the spinal cord. The two parts unite for a short part of their course and again separate.

With respect to the trapezius muscle, the spinal part of the accessory nerve reaches the superior aspect of the muscle in the lower part of the neck; it descends into the back, deep to the muscle and ramifies the muscle from the deeper aspect. The trapezius also receives branches from the cervical plexus (C3, C4 spinal nerves) which carry pain and proprioceptive fibres.

Dorsal Scapular Nerve

The dorsal scapular nerve arises from root C5 of the brachial plexus. It passes backwards and downwards through the lower part of the neck (where it pierces through the scalenus medius muscle) to reach the anterior aspect of the levator scapulae. It then descends into the back to reach the anterior (i.e., deep) aspect of the rhomboideus muscles. Here, it is accompanied by the dorsal scapular artery (or the deep branch of the transverse cervical artery). The dorsal scapular nerve supplies rhomboideus major and minor and gives a branch to the levator scapulae too.

Clinical Correlation

- As several muscles cross the region of the inferior angle of scapula, a small triangular gap is created. The triangle has its apex pointing superiorly and the base placed inferiorly. The superior horizontal border of latissimus dorsi forms the base. The other two sides of the triangle are formed by the inferolateral border of trapezius medially and the medial border of scapula laterally. This place is used by clinicians to hear the sounds of posterior parts of lung during auscultation and therefore, the triangle is called the 'triangle of auscultation'. If the scapulae are drawn forwards by folding the arms across the chest, the triangle widens.
- Injury to the dorsal scapular nerve causes paralysis of the rhomboids. The scapula on the affected side is located farther from the midline than the normal side.

contd...

Clinical Correlation *contd...*

- Testing the action of trapezius—if the shoulder is shrugged against resistance and if the muscle is normal, the upper border of the muscle can be felt easily (the same test can be done for testing the spinal accessory nerve too).
- Testing the action of latissimus dorsi—if the arm is first abducted to 90 degrees and then adducted against resistance, the anterior aspect of the muscle can be felt as the posterior axillary fold (the same test can be done for testing the thoracodorsal nerve).
- Testing the action of rhomboids—if the individual places his/her hands on the hips and then pushes the elbows against resistance, the rhomboid muscles can be felt along the medial borders of the two scapulae.

SCAPULAR REGION

MUSCLES OF SCAPULAR REGION

The scapular region has muscles which take origin from the scapula and gain insertion into the humerus. These are the scapulohumeral or intrinsic shoulder muscles and they are the:

- Deltoid muscle (Table 14.4 and Fig. 14.9)
- Supraspinatus (Table 14.5)
- Infraspinatus (Table 14.6 and Fig. 14.10)
- Teres minor (Table 14.6 and Fig. 14.11)
- Teres major (Table 14.6 and Figs 14.12 and 14.13)
- Subscapularis (Table 14.7 and Fig. 14.13)

Additional Notes on Deltoid

The deltoid is a powerful muscle and is shaped like the inverted Greek letter delta. It forms the rounded contour of the shoulder. The lateral border of the acromion presents four tubercles from which four fibrous septa descend into the muscle. From the deltoid tuberosity, three fibrous septa ascend and intervene between the

Table 14.4: Deltoid

Origin	• Upper surface and anterior border of lateral one-third of clavicle (anterior fibres) • Lateral margin and upper surface of acromion • Lower lip of crest of spine of scapula (posterior fibres)
Insertion	Deltoid tuberosity on lateral aspect of shaft of humerus
Nerve supply	Axillary nerve (C5, 6) branch of posterior cord of brachial plexus
Action	• Abduction of arm at shoulder joint up to 90 degrees (acromial fibres) • Flexion and medial rotation of humerus (anterior fibres) • Extension and lateral rotation of humerus (posterior fibres)

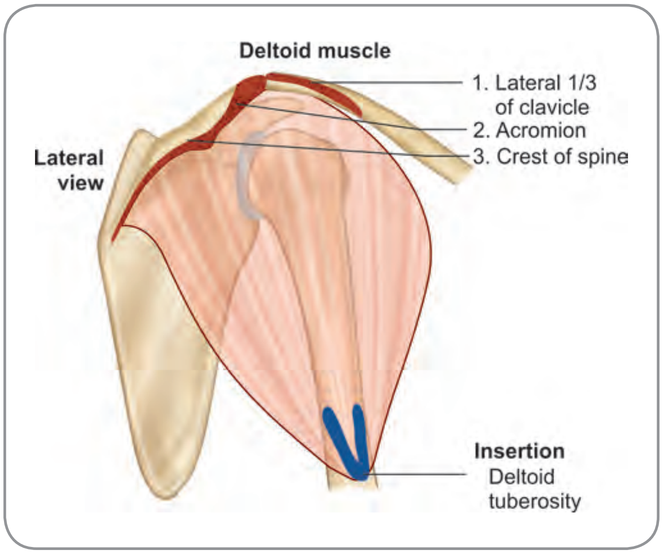


Fig. 14.9: Attachments of deltoid muscle

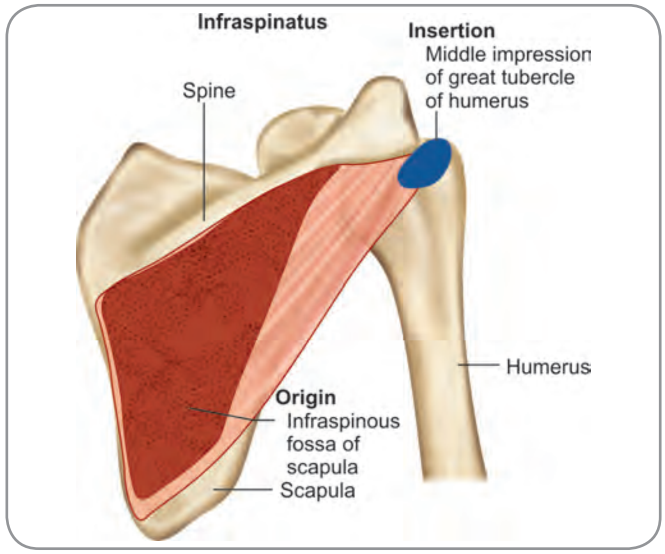


Fig. 14.10: Attachments of infraspinatus

Table 14.5: Supraspinatus

Origin	Medial two-thirds of supraspinous fossa in the dorsal surface of scapula
Insertion	Greater tubercle of humerus (uppermost impression)
Nerve supply	Suprascapular nerve (C5, 6) branch of upper trunk of brachial plexus
Action	• Stabilises shoulder joint (along with other muscles around the joint) • Abduction of arm (first few degrees)
Notes	The muscle passes under the coracoacromial arch

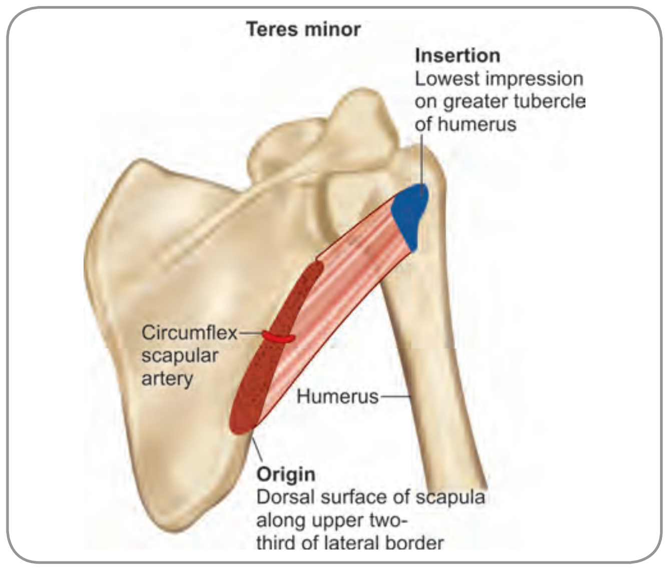


Fig. 14.11: Attachments of teres minor

Table 14.6: Infraspinatus, teres major and teres minor

Muscle	Infraspinatus	Teres minor	Teres major
Origin	Medial two-thirds of infraspinous fossa in the dorsal surface of scapula	Upper two-thirds of lateral border of dorsal surface of scapula	Lower one-third of lateral border of dorsal surface of scapula, and the inferior angle of scapula
Insertion	Posterior aspect of upper end of humerus, middle impression on greater tubercle	Posterior aspect of upper end of humerus, lowest impression on greater tubercle	Anterior aspect of upper end of humerus, on medial lip of intertubercular sulcus
Nerve supply	Suprascapular nerve (C5, 6)	Axillary nerve (C5, 6)	Lower subscapular nerve (C6, 7) branch of posterior cord of brachial plexus
Action	• Both these muscles are adductors and lateral rotators of the humerus • They stabilise the shoulder joint and strengthen the posterior part of the capsule • During abduction of the arm (by de toid and supraspinatus) their downward pull neutralises the upward pull of the deltoid and prevents the head of the humerus from getting stuck under the coracoacromial arch (the subscapularis has a similar role)		• Adductor and medial rotator of arm • Helps in extension of arm • Aids abduction of the arm just like the infraspinatus • Strengthens capsule of shoulder joint and stabilises it

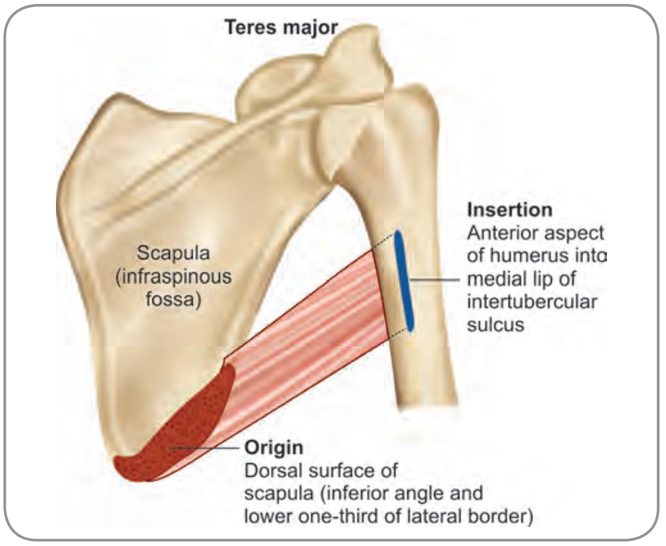


Fig. 14.12: Attachments of teres major

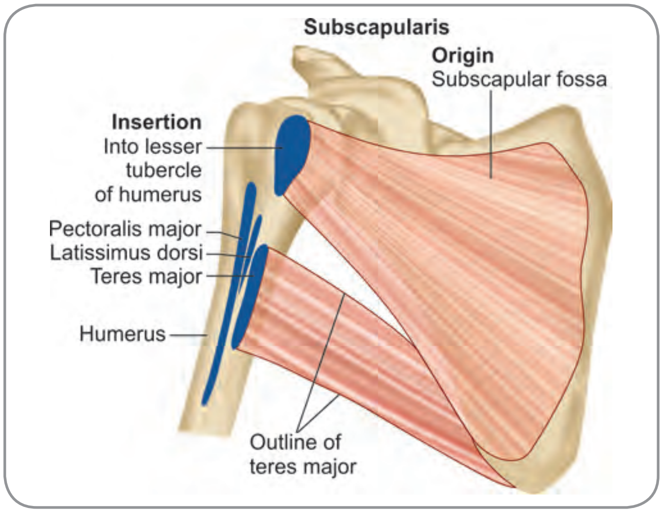


Fig. 14.13: Attachments of subscapularis–Teres major is also shown; Note the various insertions in the intertubercular sulcus

four The adjacent surfaces of these septa provide origin for multipennate fibres which form the intermediate portion of the muscle. These multipennate fibres give the muscle its power of contraction at the cost of range of movement. The unipennate muscle fibres of the anterior and posterior portions help in increasing the range of movement.

Relations of the Deltoid

The deltoid muscle covers the region of the shoulder from the lateral side, the front and the back. It therefore covers a large number of structures. These structures are:

- ***Bones:*** Upper end of the humerus including the greater and lesser tubercles, intertubercular sulcus, upper part of shaft and surgical neck; coracoid process of scapula;
- ***Muscles:*** Pectoralis minor, origins of the long head of biceps, short head of biceps, coracobrachialis and long and lateral heads of triceps, insertions of pectoralis major, teres major, latissimus dorsi, supraspinatus, infraspinatus, teres minor and subscapularis;
- ***Nerve(s):*** Axillary nerve;
- ***Vessels:*** Anterior and posterior circumflex humeral arteries;
- ***Joint and ligaments:*** Shoulder joint with its ligaments and the coracoacromial ligaments;
- ***Bursae:*** A number of bursae; however, the most important is the subacromial bursa which intervenes between the coracoacromial arch and supraspinatus.

Table 14.7: Subscapularis

Origin	Medial two-thirds of subscapular fossa in the costal surface of scapula
Insertion	Lesser tubercle of humerus
Nerve supply	Upper and lower subscapular nerves (C5, 6, 7) branches of posterior cord of brachial plexus
Action	• Adductor and medial rotator of arm • Helps in extension of arm • Its downward pull on the humerus cancels the upward pull of the deltoid and allows smooth abduction of the arm • Strengthens capsule of shoulder joint and stabilises it These actions are the same as those of the teres major
Notes	The subscapularis and teres major form the posterior wall of the axilla. The contents of the axilla lie over them

Functional Aspects

Parts of deltoid can act separately or together.

- When all the three parts act together, deltoid produces abduction of the arm. However, isolated contraction of deltoid does not lead to abduction. For abduction to be initiated, supraspinatus has to act. In the neutral position of the arm (or when it is lying on the side of the trunk), line of pull of deltoid is parallel to or coincides with the humerus. So, the muscle is not able to abduct but can only pull the humerus directly up. When supraspinatus contracts, the arm is lifted and abduction effected. Deltoid, then acts as an abductor.
- First 15 degrees of abduction is brought about by supraspinatus; deltoid then takes over and is fully effective till 90 degrees of abduction. Subscapularis, infraspinatus and teres minor act as synergists for this movement. Further abduction carries the arm above the horizontal and brings it closer to the head; abduction and elevation merge; the arm is brought vertically up to a position which is almost the opposite of its neutral state. Abduction beyond 90 degrees is produced by additional contribution from scapula. Forward

rotation of the scapula occurs at the scapulothoracic joint. For every 15 degrees of elevation, the shoulder joint contributes 10 degrees and rotation of scapula contributes 5 degrees. Muscles responsible for scapular rotation are serratus anterior and trapezius.

- Abduction by deltoid can also be brought into action by leaning to one side when gravity initiates the movement and the arm is brought away from the trunk.
- The anterior and posterior parts of the muscle act as guy ropes to steady the arm during later phases of abduction.
- The anterior and posterior parts of the muscle cause arm swing during walking; the anterior part causes flexion along with pectoralis major; the posterior part causes extension along with latissimus dorsi.
- Deltoid has a role to play when the arm is in neutral position too. It resists downward displacement of the humerus which can happen due to gravity or while lifting weight. It also holds the head of humerus in place during various movements of the upper limb.

Clinical Correlation

- ***Paralysis of deltoid:*** Paralysis of deltoid may occur when there is injury to the axillary nerve especially in fracture of surgical neck of humerus. There will be loss of sensation on the lateral side of the upper part of the arm with loss of abduction of arm. Because of muscular atrophy (when the muscle is paralysed for a long time), the rounded contour of the shoulder is lost and there may be a slight hollow below the acromion.
- To test the deltoid muscle, the examiner first abducts the patient's arm to 15 degrees He then asks the patient to continue abduction against resistance. If the muscle is normal, it can be well seen and felt. The test is preferably done with the patient in supine position to avoid the effect of gravity.
- Deltoid is the common site for intramuscular injections

Additonal Notes on the Scapulohumeral Muscles

- Both the teres muscles are rounded and so the name (Latin teres=round).
- Teres major is the most important stabiliser of the head of humerus in the glenoid socket.
- Subscapularis is the primary medial rotator of the arm. Fibrous partitions extend into the subscapularis muscle mass from the costal surface of scapula (also called the subscapular fossa); these partitions provide the subscapularis a multipennate structure resulting in efficient contraction. The roots of the partitions on the subscapular fossa are usually ossified and are seen as oblique lines on the bone. The tendon of the muscle, on its way to its insertion to the lesser tubercle of humerus, grooves the anterior border of the glenoid fossa; as a result, the glenoid obtains a pear like appearance.
- Both teres minor and infraspinatus are lateral rotators.

Musculotendinous Cuff of Shoulder

Four of the scapulohumeral muscles form a protective sheath for the glenohumeral joint; hence they are called the muscles of the musculotendinous cuff or the rotator cuff muscles. The tendons of the subscapularis, teres minor, supraspinatus and infraspinatus flatten at their insertions and their edges unite with each other. In this way a strong cuff (covering) is formed for the shoulder joint. The tendons also blend with the fibrous capsule of the joint. This is an important factor in giving strength and stability to the joint. Tone of the rotator cuff muscles holds the larger humeral head in a relatively shallow glenoid socket. All these muscles except supraspinatus are rotators of the humerus and thus the name ***rotator cuff***.

Clinical Correlation

The cuff does not extend on to the inferior aspect of the shoulder joint, leaving a weak region through which dislocation of the head of the humerus can take place much more easily than in any other direction.

- ***Rupture of the tendinous cuff*** involves injury mainly to the supraspinatus tendon.
  - It is more likely to occur in old persons because of degeneration with age.
  - The patient is unable to initiate abduction at the shoulder joint, but can maintain it once the arm is partially abducted.
- ***Strain of the supraspinatus*** is common in persons who have to work for long periods with the arms in slight abduction (e.g., typists) It can cause distressing and persistent pain.
  - The ***subacromial bursa*** lies deep to the coracoacromial a ch and the adjoining part of the deltoid muscle. The bursa facilitates abduction at the shoulde joint.
  - When the bursa is inflamed (***subacromial bursitis***), pressure over the deltoid just below the acromion elicits pain, but pain cannot be elicited after abduction of the arm (because the bursa is now under the acromion.) This is called ***Dawbarn's sign***.
  - Subacromial bursitis s usually associated with inflammation of the supraspinatus tendon.

Development

- Muscle precursor cells migrate from the somitic (myotomic) tissue to the somatopleure of the limb bud. Early in development, these cells develop into a precursor muscle mass. As the limb bud elongates and grows, this precursor muscle mass divides into two—the ventral and the dorsal premuscle masses. In line with the development of the premuscle masses, the nerves entering into the limb bud also get grouped into ventral and dorsal nerves. The ventral premuscle mass is supplied by the ventral nerves and the dorsal mass by the dorsal nerves.
- Trapezius and sternocleidomastoid muscles arise from a common premuscle mass in the occipital region (proximal to the myotomic tissue that migrates into the limb bud). As the mass enlarges in size, it extends to the scapular region and gets attached to adjacent structures.

contd...

Development *contd...*

- Levator scapulae, rhomboidei major and minor and serratus anterior arise from a common premuscle mass in the upper cervical region and undergo extensive migration to reach their adult levels.
- Subscapularis, teres major (scapulohumeral group) and latissimus dorsi (posterior axioappendicular group), though belonging to different groups in the adult, have originated from the same premuscle mass. Nerve to teres major usually supplying a twig to latissimus dorsi and the slip of attachment to latissimus dorsi from the inferior angle of scapula in association with teres major testify the common origin.

Quadrangular and Triangular Spaces

When the scapulohumeral muscles are viewed from behind, a gap between the lower border of teres minor and the upper border of teres major can be seen. More anteriorly, the lower border of the subscapularis forms the upper boundary of the gap. The gap is divided into medial and lateral parts by the long head of the triceps. The medial part is triangular in shape and is called the ***triangular space***. The lateral part of the gap is quadrangular in shape and so called the ***quadrangular space*** (Fig. 14 14)

Triangular Space

This space is close to the scapula; its upper border is formed by teres minor (posteriorly) and subscapularis (anteriorly); lower border is formed by teres major. The lateral boundary is formed by the long head of the triceps. The circumflex scapular branch of the subscapular artery passes through this space.

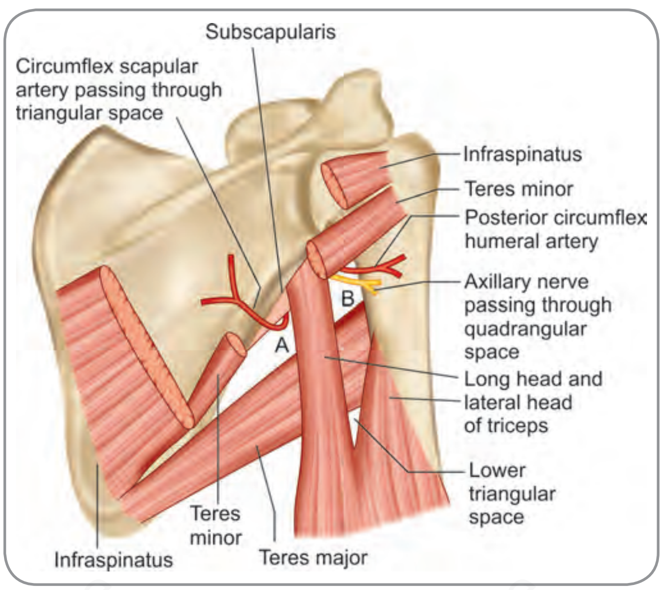


Fig. 14.14: Diagram to show **A.** Triangula space and **B.** quadrangular space

Quadrangular Space

This space is close to the humerus; its upper border is formed by teres minor and subscapularis; lower border is formed by teres major. The medial border is formed by the long head of the triceps and the lateral border by the surgical neck of the humerus.

Structures passing through this space are the axillary nerve and the posterior circumflex humeral artery. It can be seen that the upper and lower borders for both the spaces are the same. Since both teres minor and subscapularis clothe the lateral border of scapula, the upper border can be described to be formed of scapula.

Lower Triangular Space

Just below the teres major (in the arm), another triangular space can be made out; it is between the humerus (laterally) and the long head of the triceps (medially). The boundaries of this space are teres major superiorly, long head of triceps medially and shaft of humerus laterally. The radial nerve and the profunda brachii artery pass through this space to reach the back of arm. Since the space close to the scapula is also triangular in shape, it is customary to describe it as the upper triangular space and the space in the arm as the lower triangular space.

NERVES OF SCAPULAR REGION

The nerves of the scapular region are the upper and lower subscapular nerves, the suprascapular nerve and the axillary nerve.

The ***upper subscapular nerve*** (fibres from C5) arises as a side branch of the posterior cord of brachial plexus, passes posterior and enters the subscapularis; it supplies the superior portion of subscapularis. The ***lower subscapular nerve*** (fibres from C6) also arises as a side branch of the posterior cord. Passing down, it enters the teres major to supply it and also give a branch to the inferior portion of subscapularis.

Suprascapular Nerve (Fig. 14.15)

The suprascapular nerve is a branch of the upper trunk of the brachial plexus and conveys fibres from C5, C6. The nerve passes backwards above the clavicle and over the shoulder. As it does so, it lies deep to the trapezius. Reaching the upper border of the scapula, it passes backwards through the suprascapular notch (below the transverse scapular ligament) to enter the supraspinous fossa and supplies the supraspinatus.

The nerve then winds around the spinoglenoid notch, enters the infraspinous fossa where it ends by supplying the infraspinatus. It also gives branches to the shoulder joint and to the acromioclavicular joint.

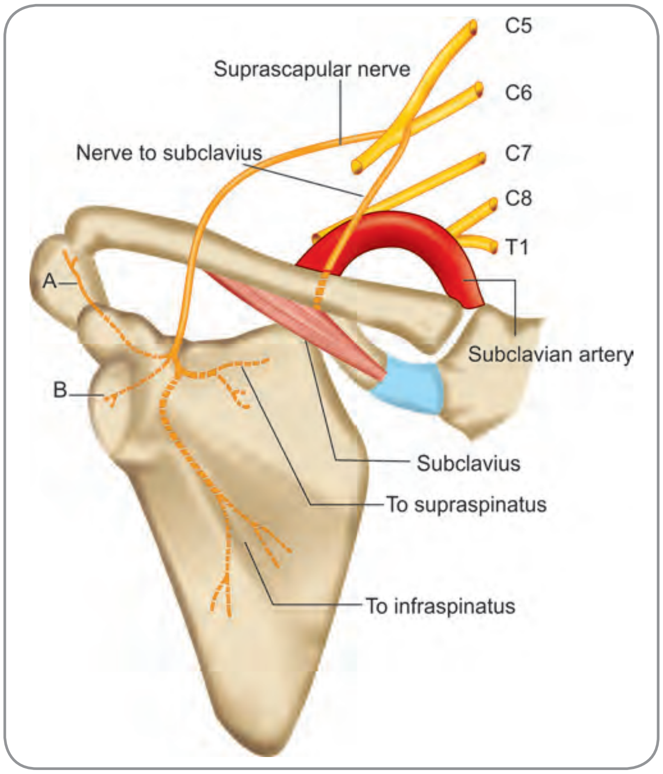


Fig. 14.15: Scheme to show the course of the suprascap lar nerve and the nerve to the subclavius; **A.** Branch to acromioclavicular joint, **B.** Branch to shoulder joint

Axillary Nerve

The axillary nerve (Fig. 14.16) supplies the deltoid and the teres minor and is also called the circumflex humeral nerve. It is the smaller terminal branch of the posterior cord (the larger terminal branch being the radial nerve) of the brachial plexus and conveys fibres from C5 and C6 spinal nerves. At its origin, it lies behind the axillary artery lateral to the radial nerve. It descends over the subscapularis and reaching the lower border of the muscle, it passes backwards through the quadrangular space (described above), in company with the posterior circumflex humeral artery. As it passes through the space, it is closely related to the capsule of the shoulder joint which lies immediately above it. The nerve ends by dividing into an anterior and a posterior branch.

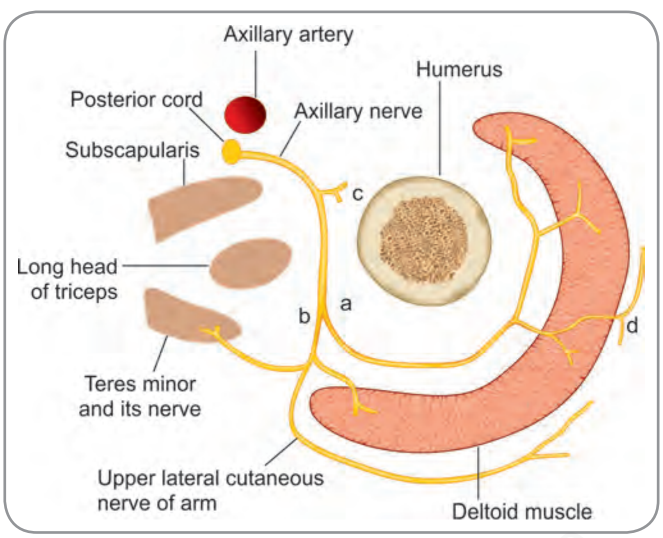


Fig. 14.16: Scheme to show the course and distribution of the axillary nerve– **a.** Anterior branch **b.** Posterior branch **c.** Branch to shoulder joint **d.** Cutaneous twig from anterior branch

- The ***anterior branch*** passes laterally and forwards round the surgical neck of the humerus and ends by supplying the del oid. Some ramifications pass through the deltoid to reach the skin.
- The ***posterior branch*** gives a twig to the posterior part of the deltoid and another to the teres minor which forms a pseudoganglion. The terminal part of the posterior branch pierces the deep fascia and becomes the ***upper lateral cutaneous nerve of the arm***. This nerve supplies the skin over the lower part of the deltoid muscle. (The skin over the upper part of the deltoid is supplied by the lateral supraclavicular nerves). The axillary nerve also gives a branch to the shoulder joint. The axillary nerve obeys the Hilton's law which states that a nerve which supplies a joint also innervates the muscle and the skin overlying that joint

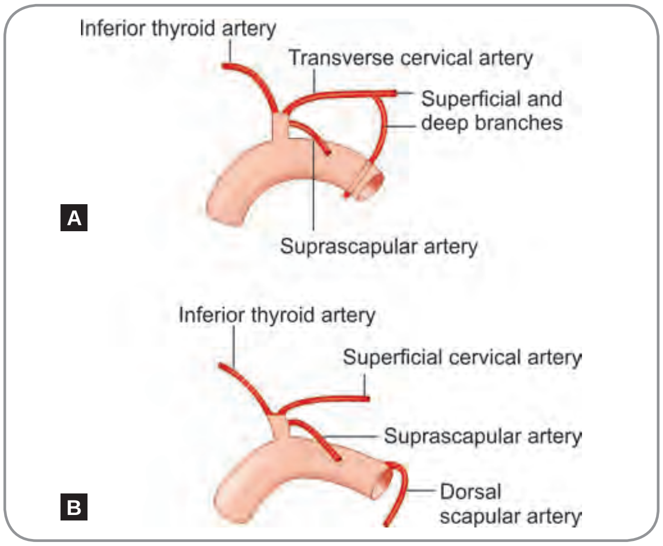
Clinical Correlation

The axillary nerve can be injured in a fracture through the surgical neck of the humerus. The deltoid is paralysed.

VESSELS OF SCAPULAR REGION

In the back and scapular region are seen arteries which begin in the neck as direct or indirect branches of the subclavian artery.

The subclavian artery is a branch of the brachiocephalic trunk in the right side and arch of aorta in the left side. Similar to the axillary artery getting divided into three parts by the teres minor muscle, the subclavian artery is divided into first, second and third parts by the scalenus anterior muscle. A short artery called the thyrocervical trunk arises from the junction of the first and third parts of the subclavian artery (Figs 14.17A and B). Its branches establish arterial anastomoses with the branches of the axillary artery. Of the branches of the subclavian artery, the suprascapular artery (branch of first part of subclavian artery), the deep branch of transverse cervical artery (branch of first part) and the deep branch of dorsal scapular artery (branch of third part) form anastomoses with the branches of axillary artery.



Figs 14.17A and B: Two patterns of branching of the thyrocervical trunk

Deep Branch of Transverse Cervical Artery

The ***deep branch*** of the transverse cervical artery (or the dorsal scapular artery) passes laterally and backwards in the lower part of the posterior triangle of the neck to reach the superior angle of scapula. It then runs along the medial border of the scapula up to the inferior angle. In this part of its course it lies, at first deep to the levator scapulae, then deep to the rhomboideus muscles and supplies these muscles. It gives branches which pass ventral or dorsal to the scapula to anastomose with the suprascapular and subscapular arteries.

Suprascapular Artery

From its origin, it runs laterally behind the clavicle. It then passes backwards to reach the superior border of the scapula where it passes above the transverse scapular ligament and enters the supraspinous fossa. After giving some branches to the supraspinatus, it passes into the infraspinous fossa by passing through the spinoglenoid notch. The branches of the suprascapular artery are:

- Muscular branches to supraspinatus, infraspinatus, sternocleidomastoid, subclavius and subscapularis.
- Cutaneous branches to the upper part of the chest (suprasternal branch) and to the acromial region (acromial branch).
- Articular branches supply the shoulder joint and the acromioclavicular joint.
- The artery also establishes several anastomoses as described below.

Anastomoses around the Scapula

- On the back of the body of the scapula, the suprascapular artery anastomoses with the deep branch of the transverse cervical artery and with the circumflex scapular branch of the subscapular artery (a branch of axillary artery) (Fig. 14.18).

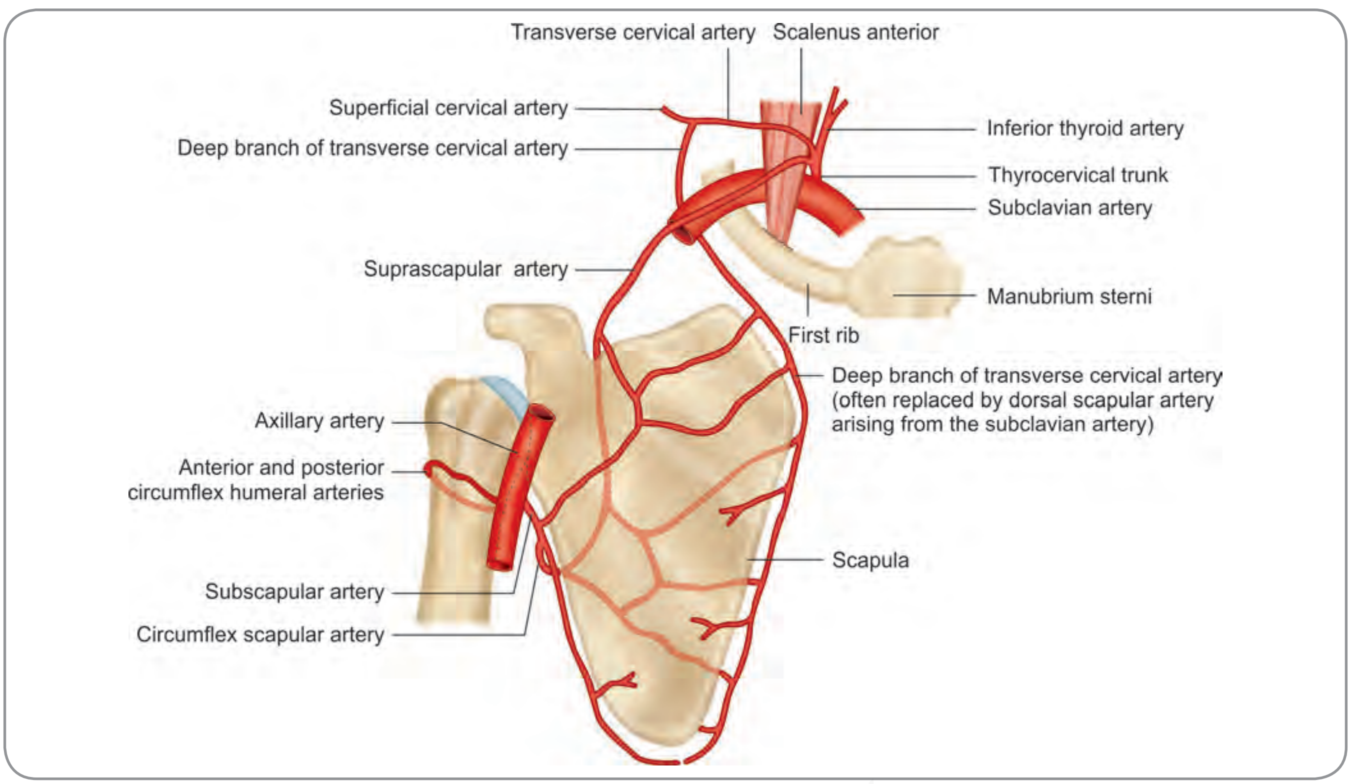


Fig. 14.18: Anastomoses around the scapula

- On the ventral surface of the body of the scapula, branches of the suprascapular artery anastomose with the subscapular artery (branch of axillary artery) and with the deep branch of the transverse cervical artery.
- Over the acromion, branches of the suprascapular artery anastomose with the thoracoacromial branch and posterior circumflex humeral artery (both branches of axillary artery).

Clinical Correlation

It may be noted that the anastomoses around the scapula connect the first part of the subclavian artery to the third part of the axillary artery. The anastomotic connections serve as collateral channels in case of obstruction to the arterial trunks between these levels. The collaterals take time to become effective and are useful in gradual obstruction of the artery. If the axillary artery has to be ligated the collateral circulation may be inadequate.

Multiple Choice Questions

1. One of the rotator cuff muscles is not a rotator of the humerus. Which is it?
   a. Supraspinatus
   b. Infraspinatus
   c. Subscapularis
   d. Teres minor

2. Abduction of arm beyond 90 degrees is produced by:
   a. Gravity acting on the arm
   b. Contribution from scapular rotation
   c. Contraction of teres major
   d. Action of the anterior fibres of deltoid in isolation

3. The dorsal scapular nerve, apart from supplying the rhomboideus major and the rhomboideus minor, also supplies the:
   a. Levator scapulae
   b. Subscapu aris
   c. Serratus anterior
   d. Infraspinatus

4. Flexion–extension of shoulder take place in a plane:
   a. Parallel to the plane of scapula
   b. Parallel to the coronal plane of the body
   c. Perpendicular to the plane of scapula
   d. Perpendicular to the coronal plane of the body

5. One of the extrinsic shoulder muscles is:
   a. Levator scapulae
   b. Deltoid
   c. Pectoralis major
   d. Supraspinatus

ANSWERS

1. a **2.** b **3.** a **4.** c **5.** a

Clinical Problem-solving

Case Study 1: A 37-year-old woman complained of pain in the upper part of the lateral aspect of her right arm. On examination, the physician noticed that the pain which was located just below the acromion, disappeared when the patient's right arm was abducted.

- What condition, do you think, the woman is suffering from?
- What sign was the physician able to elicit?
- Would you like to enquire more about the patient's work nature and responsibilities? Will such information give any clue regarding the cause of the condition?

Case Study 2: A 42-year-old man has come to the medical outpatient area for some complaints. As you happen to see him, you notice a small hollow in the upper part of his left arm.

- What would you suspect in this man?
- Does paralysis of any muscle normally cause a hollow? In what way is this hollow produced?
- What are the possibilities by which the patient's muscle could have been paralysed?

(For solutions see Appendix).

Chapter **15**

Arm

Frequently Asked Questions

- Discuss the biceps brachii with regard to its attachments, nerve supply, relations and actions. Add a note on its clinical anatomy.
- Write about the flexor muscles of the arm.
- Write notes on the brachial artery and its important branches.
- Write short notes on: (a) Coracobrachialis, (b) Brachialis, (c) Profunda brachii artery, (d) Musculocutaneous nerve.
- Write notes on triceps brachii and its actions.
- Write briefly on: (a) Articularis cub tis (b) Medial head of triceps and its role in extension of forearm, (c) Dual nerve supply to brachialis, (d) Radial nerve in the radial groove.

The arm is the proximal unit of the articulated ensemble of the upper limb and is the region between the shoulder and the elbow. It is frequently referred to as the upper arm in order to avoid confusion with the common usage of the term 'arm' meaning the entire upper limb itself. It contains a single bone, the Humerus. The humerus acts as a kind of a fulcrum providing attachment to some muscles of the shoulder and to muscles which act on the elbow joint. The arm, thus, plays a major role in maintaining the stability of the upper limb and in according power to various movements. The strengthening function of the arm is enhanced by the cross-sectional shape of the humerus. The lower part of the bone is partly and peculiarly flattened. On a cross-sectional view, it can be seen that a central rounded bar of bone is flanked by slopes on either side. The central bar extends upwards and continues into the lateral lip of the intertubercular sulcus. This central bar acts as an anchoring rod and strengthens the arm.

The arm is subdivided clearly into two compartments, the anterior and the posterior. The humerus along with the medial and the lateral intermuscular septa acts as a kind of partition dividing the two compar ments. As can be expected, the anterior compartment contains the flexors (of the elbow) and is rightly called the flexor compartment of the arm. The posterior compartment contains the extensor muscle.

At any point of time, the flexors are more powerful than the extensor; as a result, all humans are better pullers than pushers. There are a total of four muscles (flexors and extensors together) in the arm. Of these, one acts on the shoulder joint only; two act on the shoulder and the elbow and the remaining one acts on the elbow only.

FASCIAE OF THE ARM

The superficial fascia has no special features in most of the arm. However, in the upper part and over the curve of the shoulder, it may accumulate pockets of fat, especially in females.

The deep fascia of the arm is called the ***brachial fascia***. It forms a continuous sleeve around the muscles and deeper contents of the arm. Its fibres are circularly disposed aiding in the formation of the sleeve. Though, the sleeve is firm, it is not very tough and so is not discernible as a predominantly conspicuous structure as the sleeve of the thigh region is. The brachial fascia is thin over the anterior aspect and thick over the posterior aspect. It is continuous above with the fasciae covering the deltoid and pectoralis major. It is reinforced anteriorly by aponeurotic fibres from pectoralis major, medially from latissimus dorsi and laterally from deltoid. At the elbow, the brachial fascia is attached to the medial and lateral epicondyles and the olecranon and becomes continuous with the antebrachial fascia. It is pierced and traversed by the basilic vein and a few lymphatics near the mid arm.

Two intermuscular septa are given out from the deep surface of the brachial fascia and get attached to medial and lateral aspects of the humerus. The ***medial***

intermuscular septum is thicker; its humeral attachment, from above downwards, runs along the medial lip of the intertubercular sulcus, the medial supracondylar ridge and the medial epicondyle. It is perforated by the ulnar nerve, superior ulnar collateral artery and the posterior branch of the inferior ulnar collateral artery. The humeral attachment of the ***lateral intermuscular septum*** runs from the lateral lip of the intertubercular sulcus, the lateral supracondylar ridge and the lateral epicondyle. It is pierced by the radial nerve and the radial collateral branch of the profunda brachii artery.

The medial and the lateral intermuscular septa serve to divide the anterior and posterior compartments of the arm and also to provide attachments to the underlying muscles. However, owing to the thinner disposition of the deep fascia in the posterior and upper aspects, the anterior-posterior separation may be incomplete and frequently in the upper portion of the arm, the two compartments are not distinctly separate.

Clinical Correlation

In a condition called ***compartment syndrome,*** increasing oedema within a fascial compartment of a limb can lead to severe ischaemia, which is characterised by much pain. Failure to recognise the condition can in turn lead to destruction of muscle tissue and fibrosis. The condition is treated by incising the surrounding fascia to relieve the accumulated pressure.

ANTERIOR COMPARTMENT OF ARM

The anterior compartment of arm lies in front of the humerus and the two septa. It is served by the musculocutaneous nerve with a small contribution from the radial nerve Of the total four muscles of the arm, three —coracobrachialis, biceps brachii and brachialis—are in this compartment. As already noted, all the three muscles have varying relationship with the shoulder and elbow joints. Coracobrachialis crosses the shoulder joint and acts on it only; biceps brachii crosses the shoulder and the elbow and acts on both of them (and on yet another joint closely related to the elbow); brachialis crosses the elbow and acts on it only.

Muscles of the Anterior Compartment of the Arm

The muscles of the anterior compartment of arm (front of arm or the anterior brachial compartment) are the flexors; they are as follows:

- Coracobrachialis (Fig. 15.1);
- Biceps brachii (Fig. 15.2);
- Brachialis (Fig. 15.1).

Additional Notes on Coracobrachialis

This muscle gains its first point of significance by taking origin from the tip of coracoid process of scapula along with short head of biceps brachii. It forms an inconspicuous rounded ridge on the superomedial aspect of the arm and serves as an important landmark to several inner structures Pulsations of brachial artery can be felt immediately behind it. The fact that the musculocutaneous nerve pierces the muscle and the distal attachment of the muscle is close to the nutrient foramen of the humerus is utilised during surgical procedures. It flexes and adducts

Table 15.1: Muscles of the anterior compartment of the arm

Muscle	Biceps Brachii (Fig. 15.2)	Coracobrachialis (Fig. 15.1)	Brachialis (Fig. 15.1)
Origin	1. Long head from supraglenoid tubercle (on scapula) 2. Short head from tip of coracoid process (together with coracobrachialis) The two heads fuse to form a large belly which ends in a tendon	Tip of coracoid process (scapula) (in common with short head of biceps brachii)	1. Front of lower half of humerus (anteromedial and anterolateral surfaces) 2. Intermuscular septa
Insertion	Tuberosity of radius (posterior part)	Medial border of humerus (near middle of shaft)	Anterior surface of coronoid process of ulna, including tuberosity.
Nerve supply	Musculocutaneous nerve (C5,6)	Musculocutaneous nerve (C5, 6, 7)	1. Musculocutaneous nerve (C5,6). 2. Radial nerve (C7) (lateral part)
Action	1. Flexion of arm at shoulder (short head) 2. Long head keeps head of humerus in place during movements of the arm 3. Flexion of forearm (at elbow) 4. Supination of forearm	Flexor of arm	Flexor of forearm at elbow joint

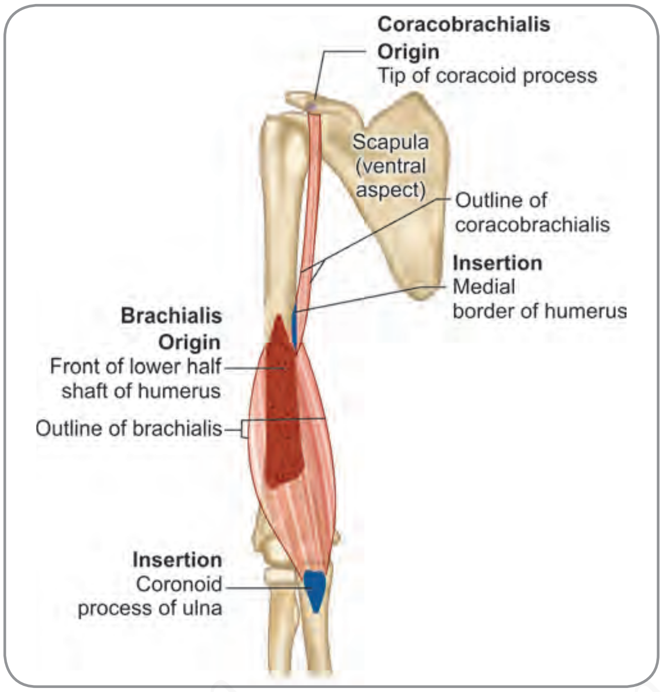


Fig. 15.1: Scheme to show the attachments of corocobrachialis and brachialis muscles

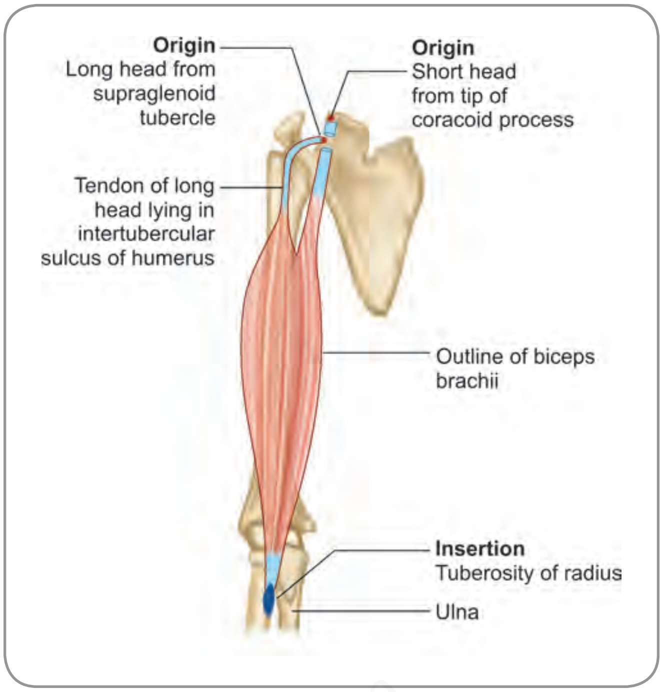


Fig. 15.2: Scheme to show the attachements of biceps brachii

the arm especially from a position of extension. Acting along with the deltoid and the long head of triceps, it functions as a shunt muscle, resisting inferior dislocation of the humeral head while carrying heavy objects. The muscle also stabilises the shoulder joint. Coracobrachialis is referred to as the ***Casser's perforated muscle*** (named after the 16th century Italian anatomist Guilio Casser) because the musculocutaneous nerve passes through it.

Additional Notes on Biceps Brachii

As the name indicates (Latin. Bi=double, caput=head), this muscle has two heads of origin—long head (caput longum) from the supraglenoid tubercle and short head (caput breve) from the tip of coracoid process (Fig. 15.2). The two heads fuse to form a large belly which ends in a single inserting tendon. The originating tendon of the long head starts within the joint cavity of the shoulder (and so, is intracapsular) from the supraglenoid tubercle. It then arches over the head of humerus to enter the intertubercular sulcus and is surrounded by a tubular sheath of synovial membrane. It emerges out of the joint from behind the transverse humeral ligament, which bridges the intertubular sulcus and converts it into a tunnel. The sulcus is also called the bicipital groove in honour of its relationship with the biceps muscle. A third head of the muscle may rarely be present. When present, the third head arises from fibres of brachialis in the distal arm. However, whatever number of heads, the inserting tendon is always single. The inserting tendon dips backwards to be inserted into the posterior part of the

Dissection

When you had studied the pectoral region and deltoid area you would have made incisions which would have partially exposed the upper part of the arm. If you want to study cubital fossa immediately after this, you can have incisions made to expose the front of arm and cubital fossa. There are two ways by which you can fashion your incisions:

1 Make a vertical incision in the middle of the anterior aspect of the arm and elbow from whatever level skin is available above (after the pectoral and deltoid region exposures) to the level of the junction of upper and middle thirds of forearm. Make two transverse incisions perpendicular to the vertical incision at the upper and lower limits of the vertical incision.

2. Make a vertical incision along the lateral border of the forearm (as seen from in front) from whatever level skin is available above (after the pectoral and deltoid exposures) to the level of the junction of the upper and middle thirds of forearm Make a transverse incision across the forearm at the lower limit of the vertical incision.

By blunt dissection, reflect the skin flaps slowly (either medially and laterally in the case of 1 or medially in the case of 2). As you clean the superficial fascia, look out for the cephalic and basilic veins. The basilica vein can be seen piercing the deep fascia in the mid arm. The median cubital vein that connects the cephalic and basilic veins can be easily made out on the anterior aspect of the cubital fossa. Locate and trace the following cutaneous nerves (Fig. 15.3):

- Medial cutaneous nerves of arm and forearm on the medial side of arm;
- Superior lateral cutaneous nerve of arm near the posterior border of eltoid;

contd...

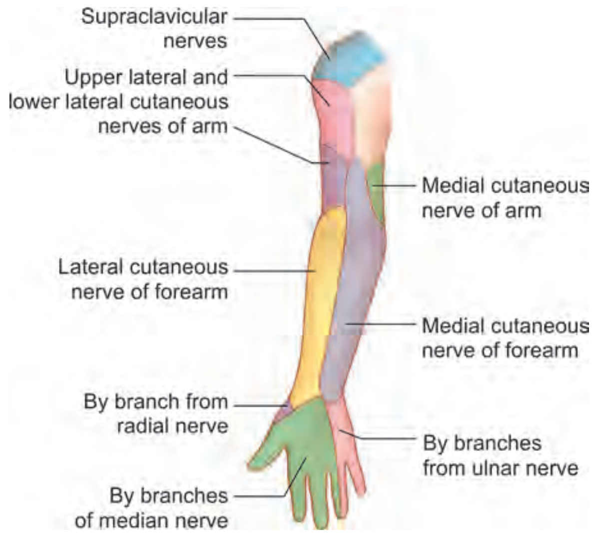


Fig. 15.3: Cutaneous nerve supply of front of upper extremity

Dissection ***contd...***

- Inferior lateral cutaneous nerve of arm and posterior cutaneous nerve of forearm on the lateral aspect of arm;
- Lateral cutaneous nerve of forearm near the biceps in the cubital region.

Once you have studied the cutaneous vessels and nerves, incise the deep fascia along the length of the arm in the midline. Clean and define the muscles of the anterior compartment. As you do so, you may encounter the intermuscular septa. Study them. Locate the brachial artery, its branches, the median, ulnar and radial nerves and study their courses and relations.

tuberosity of the radius. Before approaching radius, the tendon spirals so that the anterior surface becomes lateral. A fibrous expansion called bicipital aponeurosis (other name lacertus fibrosus), extends from the medial side of the tendon, crosses the brachial artery, winds around and blends with the deep fascia and hence attaches to the posterior border of ulna. The median cubital vein is related superficially to the bicipital aponeurosis A bursa intervenes between the tendon and the anterior part of the radial tuberosity and facilitates movement.

When a right handed person drives a screw, it is the biceps brachii which is in full action. The bicipital aponeurosis prevents pressure accumulating within the muscle during pronation-supination movements.

The muscle, though lying in the anterior compartment of the arm, has no attachment to humerus. It is actually a 'three-joint muscle' crossing the shoulder, elbow and superior radioulnar joints. It can, therefore, act on all of them. It flexes the arm (action at shoulder by short head), keeps the head of humerus in place during movements of the arm and flexes the forearm (action at shoulder and elbow by long head) and supinates the forearm (action at the superior radioulnar joint by the pull of bicipital aponeurosis). Supination is powerful only when the forearm is semiflexed (because in this position the lowest part of the tendon is in straight line with the rest of the muscle)

The effectiveness of biceps depends on the position of elbow and forearm. When the forearm is extended, it is a flexor of forearm. When the elbow flexion reaches 90 degrees and the forearm is supinated, it is a powerful flexor of forearm further. When the elbow flexion is close to 90 degrees and the forearm is pronated, the muscle is a powerful supinator.

Relations of Biceps Brachii Muscle

- ***Anteriorly:*** Pectoralis major and deltoid in the upper part; skin and fasciae in the lower part.
- ***Posteriorly:*** The shoulder joint (on which lies the short head) in the upper part; brachialis muscle, musculocutaneous nerve and supinator muscle in the lower part.
- ***Medially:*** Coracobrachialis, Brachial vessels and median nerve.
- ***Laterally:*** Deltoid and Brachioradialis.

The main blood supply is usually received from the brachial artery. Atleast eight branches arise from the artery and pass laterally to reach the deep surface of the muscle. Each of them divides into an ascending and a descending branch before entering the muscle substance. Smaller branches may arise from any of the adjacent arteries.

Additional Notes on Brachialis

This is a bulky but flattened muscle covering the entire lower half of arm. It is the main flexor of the forearm producing the greatest flexion force and being the only pure flexor. It flexes the forearm irrespective of position of pronation or supination, of presence or absence of resistance and of rapid or slow movements. In addition to initiating flexion and contracting during all demands of flexion, this muscle also sustains the flexed position. This kind of its constancy has earned it a special name—the workhorse of elbow flexors.

Clinical Correlation

- ***Testing of coracobrachialis:*** The muscle is made prominent by performing shoulder flexion against resistance; its mass can then be palpated.
- ***Testing of biceps brachii:*** The forearm is kept in supination. The elbow is then flexed against resistance. If the muscle is normal, its mass is seen as a prominent and firm arm bulge.
- ***Testing of brachialis:*** The elbow is flexed against resistance in different positions of pronation and supination. The muscle can be felt well when the forearm is semipronated and flexed against resistance.

contd...

Clinical Correlation *contd...*

- The median nerve or the brachial artery may pass deep to coracobrachialis and therefore, be compressed by the muscle.
- The tendon (of origin) of the long head of the biceps brachii lies within the capsule of the shoulder joint. In osteoarthritis of this joint, abnormal irregular projections develop from the bones concerned and friction against them can lead to inflammation (***tendinitis***). There is pain in the shoulder.
- Damage to the tendon can end in ***rupture*** of the tendon
- The tendon of the long head is subject to repetitive trauma. It moves back and forth within the intertubercular sulcus. Wear and tear causes pain. In sports activities like throwing or use of racquet, this repetitive microtrauma is increased and the tendon gets inflamed.
- The tendon of long head may get dislocated from the intertubercular sulcus either due to direct trauma or chronic bicipital tendinitis.
- Due to chronic tendinitis, the tendon of the long head may rupture and be torn away from its supraglenoid attachment. The rupture suddenly occurs with a 'pop' noise. Apart from prolonged tendinitis, other causes of a rupture are forceful flexion against resistance and repetitive overhead motion.
- ***Biceps tendon reflex*** is elicited by a tap on the biceps tendon The examiner places his thumb over the tendon and gives a tap on his thumb. There is reflex contraction of the biceps. The reflex is lost in injury to the musculocutaneous nerve or to spinal segments C5 and C6. It is exaggerated in upper motor neuron paralysis. A hung response (slow but prolonged response) occurs in metabolic disorders like thyroid malfunction.

Vessels of the Anterior Compartment

The brachial artery can be labelled as the main artery of the anterior compartment. The superior and inferior ulnar collateral arteries which also supply muscular branches to the anterior brachial muscles are branches of the brachial artery. The veins of the arm follow the standard superficial-deep venous patterns of the limb.

Brachial Artery

The brachial artery is the main artery of the arm. It begins at the lower border of the teres major as the continuation of the axillary artery. It travels down on the medial aspect of the arm and as it descends, it gradually passes forwards, so that its lower end lies in front of the elbow. It terminates at the level of the neck of the radius, by dividing into the radial and ulnar arteries. The artery is medial to the humerus at its commencement but gradually spirals anterior to the bone to reach midway between the humeral epicondyles.

Relations of the Artery

Passing through the anterior compartment, the brachial artery sinks into the cubital fossa at the elbow.

- ***Anteriorly:*** The brachial artery is superficial almost throughout its course covered only by skin and fasciae. However, two important structures cross it at two points.
  1. Middle of arm (level of coracobrachialis insertion) — median nerve crosses from lateral to medial side.
  2. Cubital fossa—bicipital aponeurosis crosses from lateral to medial side.
- ***Posteriorly:*** (from above downwards successively) long head of triceps, medial head of triceps, coracobrachialis and brachialis. The radial nerve and the profunda brachii artery separate the brachial artery from the long head of triceps.
- ***Medially:*** Medial cutaneous nerve of forearm and ulnar nerve in the upper arm; median nerve and basilic vein in the lower arm.
- ***Laterally:*** Median nerve and coracobrachialis in the upper arm; biceps tendon in the lower arm.

The brachial artery is accompanied by a pair of venae comitantes throughout its length.

Branches of the Brachial Artery (Fig. 15.4)

The branches given off by the brachial artery are the profunda brachii, superior, middle and inferior ulnar collateral arteries, deltoid branch, nutrient artery, muscular branches and the terminal branches of ulnar and radial arteries

Profunda brachii artery: Otherwise called the deep artery of the arm. This largest branch of the brachial artery arises from its posteromedial aspect, a little below the commencement of the parent vessel. It accompanies the radial nerve, passes posteriorly between the long and medial heads of triceps and then descends in the radial groove. It ends in the radial groove by dividing into the middle collateral and radial collateral branches. Its branches are:

- A ***nutrient artery*** to the humerus;
- Muscular branches to adjacent muscles;
- ***Middle collateral*** (or ***posterior descending) branch:*** Being the larger terminal branch of the profunda and arising posterior to the humerus, it descends in the substance of the medial head of the triceps and anastomoses with the recurrent branch of the posterior interosseous artery (which in turn is a branch of the common interosseous branch of the ulnar artery) behind the lateral epicondyle;
- ***Radial collateral*** (or ***anterior descending):*** Being the continuation of the profunda brachii, this artery (along with the radial nerve) pierces the lateral intermuscular septum and enters the anterior compartment of the arm; it runs along with the radial nerve in the lower lateral part of the arm and supplies the brachialis, brachioradialis and the radial nerve; it ends by anastomosing with the recurrent branch of the radial artery in front of the lateral epicondyle.

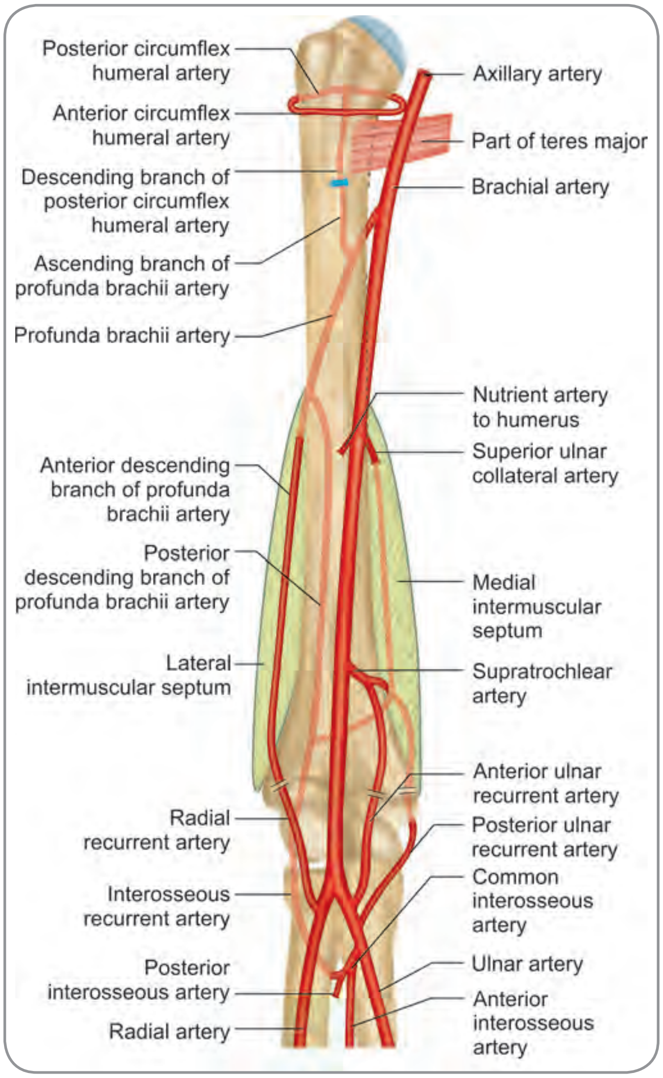


Fig. 15.4: Scheme to show the arteries of the arm and various anastomoses in the region

S***uperior ulnar collateral artery*:** Arising near the middle of the arm, it accompanies the ulnar nerve and pierces the medial intermuscular septum to enter the posterior compartment of arm. After supplying the medial head of triceps, it runs downwards to reach the back of the medial epicondyle. The artery ends by anastomosing with the posterior recurrent branch of the ulnar artery and with the inferior ulnar collateral artery (a branch of the brachial artery itself).

Inferior ulnar collateral artery: Otherwise called the supratrochlear artery, it arises from the brachial artery a little above the elbow. It first passes medially and then backwards by piercing the medial intermuscular septum. It then runs laterally behind the humerus and anastomoses with the middle collateral (posterior descending) branch of the profunda brachii artery forming an arterial arch proximal to the olecranon. It may anastomose with the interosseous recurrent artery branch of posterior interosseus artery. Before piercing the medial intermuscular septum, it gives off a branch that descends to anastomose with the anterior recurrent branch of the ulnar artery The inferior ulnar collateral artery gives branches which interconnect it with the superior ulnar collateral and posterior ulnar recurrent arteries.

Middle ulnar collateral artery: If present, this artery arises between the superior and inferior ulnar collateral arteries and descends to the anterior aspect of the medial epicondyle. It supples some twigs to the triceps muscle and ends by anastomosing with the anterior ulnar recurrent artery.

Muscular branches: These branches of the brachial artery supply the coracobrachialis, biceps brachii and brachialis muscles. Atleast eight separate branches arise for the biceps.

Nutrient artery to the humerus: This branch arises in the mid arm and enters the nutrient canal of the bone near the insertion of the coracobrachialis. It is directed distally (in keeping in line with the norm 'towards the elbow I go').

Deltoid branch: This slender branch usually arises at mid arm or proximal to it and ascends between the lateral and long heads of triceps. It anastomoses with a descending branch of the posterior circumflex humeral artery.

At its lower end the brachial artery terminates by dividing into the ***radial*** and ***ulnar arteries***.

Clinical Correlation

- Brachial artery is superficial throughout its course and easily accessible. It is regularly used for measurement of blood pressure. It can also be used for stopping bleeding by applying manual pressure. The best place to compress the artery is at the mid arm level, medial to the humerus. Pressure should be applied lateralwards.
- If the brachial artery has to clamped, it should be done distal to the origin of the profunda; this way, tissue damage can be avoided. Even if the brachial artery is ligated, the ulnar and radial arteries are likely to receive adequate blood supply through the periarticular arterial anastomosis in the elbow region.
- Compression of the brachial artery may occur in fractures of the shaft of the humerus (especially in supracondylar fractures) or in dislocations of the elbow joint. Sudden occlusion of the artery or lacerating injuries to it may block arterial supply to the muscles and cause ischaemic damage. The muscles may not only be paralysed but also irrecoverably damaged.
- Fractures of humerus are very often immobilised by applying plaster casts around the affected part. A plaster cast that is too tight can be a cause for ischaemia and results can be serious if the condition is not recognised in time.
- ***Volkmann's ischaemic contracture:*** Spasm of brachial artery can occur following fractures in the region of the elbow. This reduces blood supply to muscles of the forearm and ultimately leads to their fibrosis which in turn shortens the muscles and leads to deformities of wrist and digits.

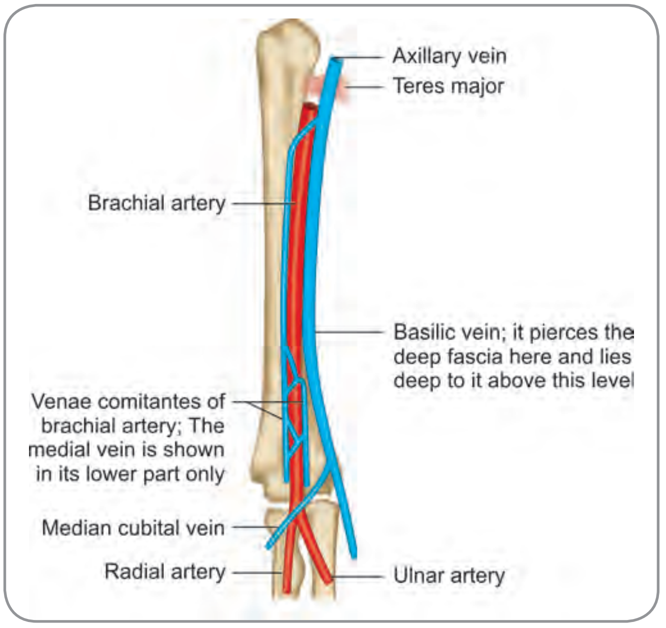


Fig. 15.5: Diagram showing veins related to the brachial artery

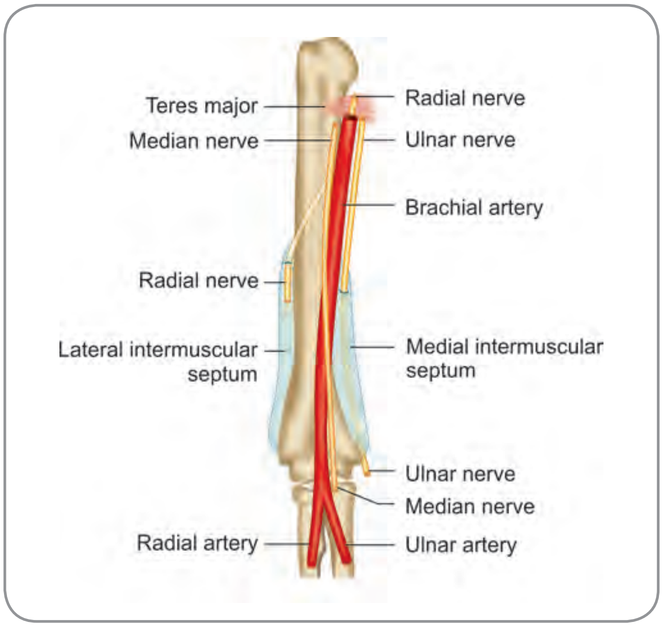


Fig. 15.6: Diagram showing nerves related to the brachial artery

Brachial Veins (Fig. 15.5)

These are the venae comitantes of the brachial artery and accompany the artery throughout its course. They are interconnected by horizontal and oblique cross communications. Near the lower margin of subscapularis they join the basilic vein and form the axillary vein. The brachial veins are the deep veins of the arm and have numerous communications with the superficial venous system subserved by the cephalic and basilic veins.

Nerves of the Anterior Compartment of Arm (Figs 15.6 and 15.7)

The main nerves to be seen in the anterior compartment of arm are the musculocutaneous nerve, the median nerve, the ulnar nerve and the superior portion of the radial nerve.

Musculocutaneous Nerve

The ***musculocutaneous nerve*** is the nerve of the anterior compartment of arm and a branch of the lateral cord of the brachial plexus. The nerve pierces the coracobrachialis and then runs downwards and laterally through the front of arm, deep to biceps and superficial to brachialis. Reaching the lateral side of arm, it crosses in front of the lateral side of the elbow to enter the forearm. Here, the nerve pierces the deep fascia and becomes superficial and is called the ***lateral cutaneous nerve of the forearm*** (lateral antebrachial nerve). As implied by its name the musculocutaneous nerve is distributed partly to muscles and partly to skin (Fig. 15.8).

The muscles supplied by it are coracobrachialis, biceps brachii and brachialis. As the lateral cutaneous nerve of forearm, it supplies the skin of the lateral half of the front of the forearm and its distal part supplies the skin of the thenar eminence.

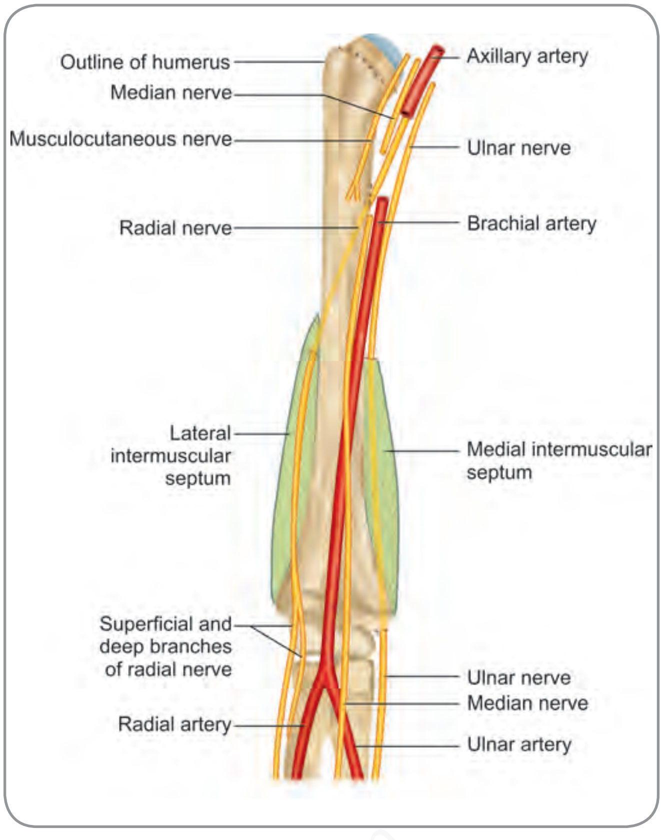


Fig. 15.7: Scheme to show the main nerves of the arm – the main arteries are included for orientation

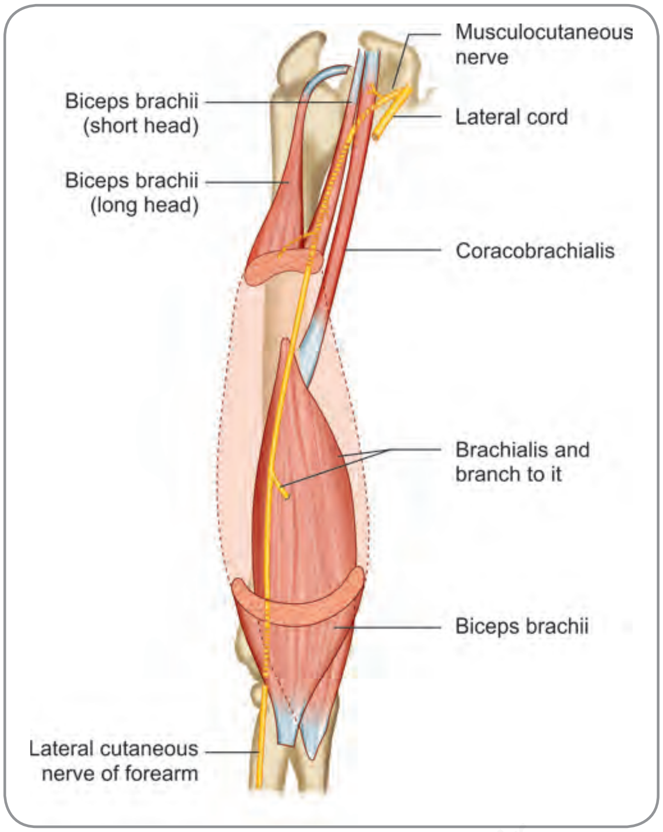


Fig. 15.8: Scheme to show the course and distribution of the musculocutaneous nerve

Clinical Correlation

Injury to the musculocutaneous nerve results in paralysis of muscles supplied. The bicipital tendon reflex is lost. Weak elbow flexion and supination can still occur by the action of brachioradialis and supinator. There is loss of sensation over the lateral side of the forearm.

Median Nerve in the Arm

Median nerve is formed by the union of the lateral and medial roots which arise from the corresponding cords of the brachial plexus. It lies lateral to the axillary artery and continues into the arm lateral to the brachial artery. Near the middle of the arm, it crosses superficial to the artery to reach its medial side and then descends to the cubital fossa. The nerve leaves the cubital fossa by passing between the superficial and deep heads of the pronator teres. It gives a branch to the pronator teres; articular branches arising near the elbow supply the elbow joint and the superior radioulnar joint; a few vascular branches may be given to the brachial artery. The median nerve does not supply any muscle in the arm.

Ulnar Nerve in the Arm

Ulnar nerve is a branch of the medial cord of the brachial plexus. At its origin, the nerve lies medial to the axillary artery (between it and the axillary vein). It runs down into the front of arm where it lies medial to the brachial artery At the middle of the arm, the nerve passes into the posterior compartment by piercing the medial intermuscular septum and descends between this septum and the lower part of medial head of triceps to reach behind the medial epicondyle of the humerus. It enters the forearm by passing deep to the tendinous arch joining the humeral and ulnar heads of the flexor carpi ulnaris. The ulnar nerve does not give off any branches in the arm.

Radial Nerve in the Arm

The ***radial nerve*** is seen for a short distance in the front of arm. It then enters the back of the arm. Its complete course and branches in the arm will be considered while describing the posterior compartment of arm.

POSTERIOR COMPARTMENT OF ARM

The posterior compartment of arm lies behind the humerus and the two intermuscular septa. It is served by the radial nerve and has only one muscle – the triceps brachii.

Additional Notes on Triceps

The long head is the scapular head and forms the medial boundary of the quadrangular space. The lateral and medial heads are the humeral heads. The medial head has an extensive origin from the lower part of the entire posterior surface of the humerus, from the medial intermuscular septum and from the lower part of the lateral intermuscular

Table 15.2: Triceps (Fig. 15.9)

Origin	1. Long head from infraglenoid tubercle of scapula 2. Lateral head from ridge on posterior aspect of humerus 3. Medial head from posterior surface of humerus below the radial groove, and from intermuscular septa.
Insertion	Olecranon process of ulna (posterior part of superior surface)
Nerve supply	Radial nerve (C6, 7, 8)
Action	1. Extension of forearm at elbow joint 2. Long head helps in bringing back the abducted or extended arm to the side of the body
Note	The ridge from which the lateral head arises corresponds to the upper part of the lateral border of the bone. The ridge extends from the greater tubercle to the deltoid tuberosity. It lies above the radial groove.

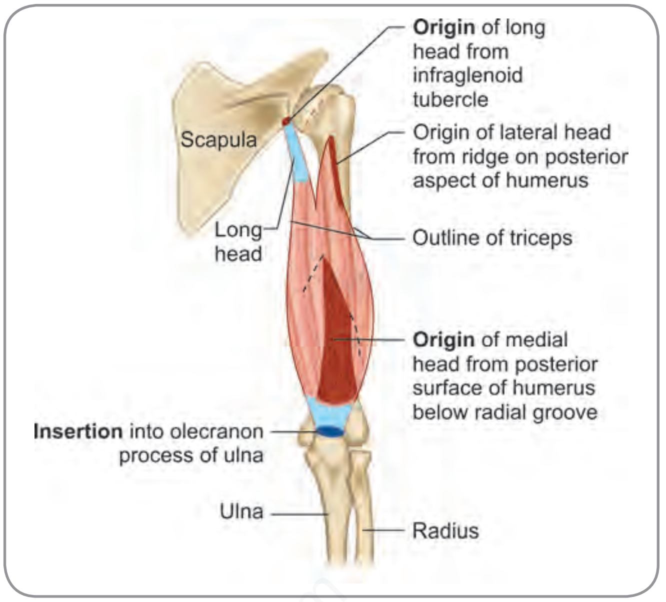


Fig. 15.9: Scheme to show the attachments of triceps muscle

septum. Some of its muscular fibres may directly be attached to the olecranon (Fig. 15.9). The common inserting tendon of the triceps has two laminae. The superficial lamina is on the surface where fibres from all three heads converge; the deep lamina is embedded within the substance of the muscle. The two laminae unite just above the elbow and insert into the upper part of the olecranon. On the lateral aspect, a band of fibres continue from the triceps tendon over the anconeus to blend with the antebrachial fascia. This band forms the tricipital aponeurosis.

The branch from the radial nerve to the long head is given in the axilla, to the lateral head in the spiral groove and the two branches to the medial head are given in the axilla and in the spiral groove.

Triceps is the major extensor of the forearm The medial head is active during all types of extension and so is the workhorse of forearm extension. The lateral and long heads are active during extension against resistance. The long head, which is the least active of the three heads, helps in bringing back the abducted or extended arm to the side of the body. It also acts as a shunting muscle in stabilising the shoulder joint and resisting downward displacement of the humeral head. Thus, the long head performs as an adductor and sustains the adduction. The lateral head, though the strongest, comes into play only against resistance.

A small slip from the medial head is inserted into the capsule of the elbow joint. This slip is called the ***articularis cubiti*** or the ***subanconeus muscle*** It pulls up the posterior part of the capsule during extension of the forearm. Articularis cubiti is the upper limb counterpart of the articularis genu or the subcrureus muscle (part of the vastus intermedius) of the lower limb

A subtendinous olecranon bursa is present between the olecranon and the triceps tendon.

Relations of Triceps Brachii Muscle

- ***Anteriorly:*** Humerus and the intermuscular septa; radial nerve on the lateral aspect in the mid arm level.
- ***Posteriorly:*** Skin and fasciae.
- ***Medially:*** Skin and fasciae in the upper part; ulnar nerve and superior ulnar collateral vessels in the lower part.
- ***Laterally:*** Skin and fasciae.

The long head descends between the teres minor and the teres major and divides the space between the teres muscles and the humerus into the triangular (upper triangular) and quadrangular spaces. The triangular space, bounded above by teres minor, below by teres major and laterally by the long head, transmits the circumflex scapular vessels. The quadrangular space, bounded above by subscapularis, teres minor and shoulder capsule, below by teres major, medially by long head and laterally by humerus, transmits the axillary nerve and the posterior circumflex humeral vessels. The lateral and the medial heads make most of the bulk of the muscular mass on the posterior aspect of arm. The lateral head stands out prominently in forearm extension against resistance.

Added Information

The anconeus muscle (or the anconeus quartus; Greek. ancon=elbow) is often considered as part of the triceps group though it, anatomically and functionally belongs to the posterior compartment of forearm. Developmentally, the anconeus is considered an extension of the triceps and has the same nerve supply (radial nerve). It actually tenses the elbow joint capsule and prevent it from being pinched off during extension of forearm. It acts along with the triceps and helps in extension per se.

Vessels of the Posterior Compartment of Arm

The main artery of the posterior compartment is the profunda brachii artery. It runs the major part of its course in the posterior compartment and several of its branches are given out here (for sake of descriptive convenience, the artery is discussed in the anterior compartment of arm). The veins of the compartment are the accompanying veins of the arteries and drain into the venae comitantes of the brachial artery.

Nerve of the Posterior Compartment

Both by development and by anatomical location, the radial nerve is the nerve of the posterior compartment.

Radial Nerve

The ***radial nerve*** is the main continuation of the posterior cord of the brachial plexus. In the axilla it lies behind the third part of the axillary artery. In the upper part of the

Dissection

The posterior aspect of the arm would, by now, be exposed due to various incisions made in the pectoral, scapular and deltoid regions. If not, place appropriate incisions to open up the compartment. Once the muscles are exposed, identify and define the three heads of triceps. Detach the long head from its humeral attachment and reflect it inferomedially. Locate the radial nerve and trace it to the radial groove. Now the lateral and medial heads are clearly made out. Define and study them. Trace the branches of the radial nerve to the medial head and the anconeus through the medial head. Clean up the triceps insertion to the olecranon. Define the radial nerve and trace as many of its branches as possible.

arm, it lies behind the upper part of the brachial artery. It leaves the front of arm by passing backwards (between the long and medial heads of the triceps) through the ***lower triangular space***. The nerve passes downwards and laterally and lies in the radial groove. The groove is virtually converted into a tunnel by the lateral head of triceps and the lateral intermuscular septum. Finally, it passes through an aperture in the lateral intermuscular septum to reach the cubital fossa. Here it descends between the brachialis (medially) and the brachioradialis and the extensor carpi radialis longus (laterally). The nerve ends in front of the lateral epicondyle of the humerus by dividing into superficial and deep terminal branches.

Branches of radial nerve given off in the arm are:

- ***Muscular branches:*** Branches arising from the superior segment of the nerve supply the long and medial heads of triceps. The ***branch to the medial head*** descends along the medial side of the humerus close to the ulnar nerve (and therefore, is called the ***ulnar collateral nerve***) (Fig. 5.18). In the radial groove, the nerve gives another branch to the medial head and also supplies the lateral head. One branch descends through the medial head to reach the anconeus muscle. Branches arising from the radial nerve in the lateral part of the front of arm supply the brachialis (lateral part), the brachioradialis and the extensor carpi radialis longus.
- ***Cutaneous Branches:*** The ***posterior cutaneous nerve of arm*** is given off by the radial nerve while the latter is in the axilla.

  The ***inferior*** (or ***lower***) ***lateral cutaneous nerve of arm*** (Fig. 17.39) arises from the radial nerve while the latter lies in the radial groove. It becomes superficial by piercing the lateral head of triceps; curving around the lateral side of the arm, it reaches the front of elbow. The inferior lateral cutaneous nerve supplies the skin of the lower part of the lateral surface of the arm (Figs 10.1A and 10.2A).

  The ***posterior cutaneous nerve of forearm*** (Fig. 10.2B) also arises from the radial nerve while the lat er lies in the radial groove. It becomes superficial by piercing the lateral head of triceps and descends into the posterolateral part of the forearm reaching up to the wrist. It supplies an extensive area of skin on the back of arm and on the back of forearm (Fig. 10.1B).

Added Information

- The radial nerve supplies a branch to innervate the lateral part of the brachialis muscle. This part of brachialis is a detached portion of the brachioradialis and is, developmentally a dorsal muscle (indicated by the nerve supply – by radial nerve, a dorsal nerve).
- The rest of the b achialis is developmentally a ventral muscle.
- All muscles supplied by the radial nerve and its branches are developmentally dorsal muscles; all muscles supplied by the median, musculocutaneous and ulnar nerves are developmentally ventral muscles.
- The median nerve supplies the flexors and so, its branches pass medially. The radial nerve supplies the extensors and so, its branches pass laterally. It is therefore, safe to explore, during surgical procedures, on the lateral side of the median nerve and the medial side of the radial nerve. The lateral side of median nerve and the medial side of the radial nerve are ***'sides of safety'***.

Clinical Correlation

The radial nerve can be injured at different levels in the arm

- Lesions of the nerve close to its origin from the posterior cord of the brachial plexus may be caused by pressure from prolonged use of crutches (crutch palsy). The triceps muscle is affected only if the lesion is at this level.
- Lesions of the nerve as it lies in the radial groove are commonly caused by fractures of humerus. The triceps is spared.
- Compression of the nerve against the humerus can occur if the arm is made to rest against a ***sharp edge*** or margin**.** The resting of the arm against the edge of a chair is a classic example leading to the notorious description of Saturday night palsy.
- In both radial groove and compression lesions, the triceps is not completely paralysed. The medial head may alone be affected resulting in weakened extension of the forearm. However, the muscles of the posterior compartment of forearm are affected. Paralysis of brachioradialis leads to wasting of the muscle and the radial aspect of the forearm loses its contour. Paralysis of wrist and finger extensors results in wrist and fingers drop (***wrist drop, dropped hand, carpoptosia***). The characteristic clinching sign is inability to extend the wrist at the wrist and the fingers at the metacarpophalangeal joints The wrist assumes a partially flexed (dropped) position due to the unopposed action of the flexors and gravity.

Multiple Choice Questions

1. Which muscle of the anterior compartment of arm has an extensor component nerve supply?
   a. Biceps brachii
   b. Brachioradialis
   c. Brachialis
   d. Coracobrachialis

2. Biceps brachii is a powerful supinator when:
   a. The elbow is extended and forearm pronated
   b. The elbow is extended and forearm supinated
   c. The elbow is flexed and forearm supinated
   d. The elbow is flexed and forearm pronated

3. Tricipital aponeurosis is a fascial sheath extending from the triceps muscle and blending with:
   a. Antebrachial fascia
   b. Anconeus muscle
   c. Olecranon of ulna
   d. Capsule of elbow joint

4 The ulnar collateral nerve is:
   a. The branch of radial nerve to the brachialis
   b. The branch of radial nerve to the medial head of triceps
   c. The posterior cutaneous nerve of arm
   d. The posterior cutaneous nerve of forearm

5. The triangular space bounded above by the teres minor transmits the:
   a. Circumflex scapular vessels
   b. Axillary nerve
   c. Anterior circumflex humeral vessels
   d. Radial nerve

ANSWERS

1. c **2.** d **3.** a **4.** b **5.** a

Clinical Problem-solving

Case Study 1: You had taken your grandfather to a neurologist for neurological evaluation. During the course of clinical examination, the neurologist pronated your grandfather's left upper limb and also partially extended the elbow. He then placed his thumb over a structure on the anterior aspect of the elbow and tapped his own thumb with a knee hammer

- Can you suggest as to what clinical test was the neurologist trying to perform?
- What response do you anticipate in a normal individual?
- In what conditions will there be altered responses?

Case Study 2: A 27-year-old man presented with the following signs and symptoms—inability to extend the wrist and inability to extend fingers. His wrist was partially flexed and assuming a prone position with the fingers in flexion.

- How would you describe the condition?
- Which nerve is affected?
- Why is the wrist in a position of flexion and pronation?

(For solutions see Appendix).

Chapter 16

Cubital Fossa

Frequently Asked Questions

- Discuss the cubital fossa in detail.
- Write notes on: a) Bicipital aponeurosis, (b) Contents of cubital fossa, (c) Superficial veins in the cubital fossa, (d) Median cubital vein.
- Discuss the median cubital vein and its clinical significance.
- Write briefly on: (a) Median vein of forearm, (b) Venipuncture in he cubital fossa.

The cubital fossa is a potential, triangular space (Latin. cubitus=elbow) present in front of the distal humerus and the elbow joint. It is usually filled with variable amount of fat. Superficially it is seen as a depression in the front of the elbow joint.

For descriptive purposes, the fossa can be said to have medial and lateral boundaries, a base, an apex, a roof, a floor and contents

BOUNDARIES

The boundaries are (Fig. 16.1):

- ***Medially:*** Lateral border of ***pronator teres;***
- ***Laterally:*** *Medial* border of ***brachioradialis***;
- ***Apex:*** Point of convergence of the medial and lateral boundaries;
- ***Base:*** An imaginary line connecting the medial and lateral epicondyles of the humerus.

Though, it is customary to describe the medial and lateral boundaries by identifying the closest muscle lying on the boundary, the entire muscle masses of the forearm flexors and the forearm extensors make the boundaries on the medial and lateral aspects respectively. The individual muscles are closely packed at this level where they are still part of their common (flexor or extensor) origin.

ROOF

The ***roof*** of the cubital fossa is formed by the deep fascia and is reinforced by the bicipital aponeurosis. The deep fascia here is actually the continuity of the brachial and the antebrachial fasciae. Overlying the deep fascia are the median cubital vein, the median vein of the forearm and the medial and lateral cutaneous nerves of forearm. Superficial fascia and skin form the superficial layers of the roof.

FLOOR

The ***floor*** of the fossa extends from the lower end of the arm to the upper end of the forearm. Two muscles which are

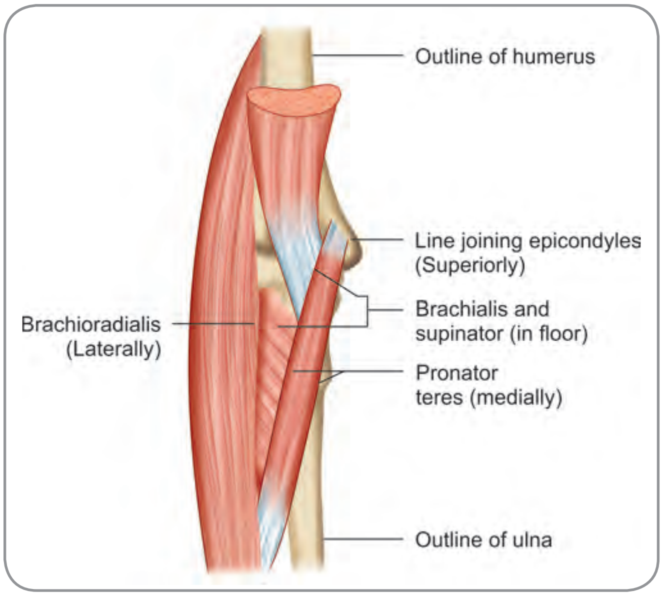


Fig. 16.1: Boundaries of the cubital fossa

closely applied to the concerned bones form the floor. The lower portion of brachialis (muscle of he arm) forms the floor of the upper part of the fossa; the supinator muscle (deep muscle of the posterior compartment of forearm) forms the floor of the lower part of the fossa.

CONTENTS

The ***contents of the fossa*** (from medial to lateral) are:
- Median nerve,
- Brachial artery,
- Tendon of the biceps brachii and bicipital aponeurosis and
- Radial nerve.

The ***median nerve*** lies medial to the brachial artery in the fossa and is anterior to brachioradialis and posterior to bicipital aponeurosis. It gives off several branches in the fossa which supply the muscles of the front of forearm (including the pronator teres). The nerve may be trapped and compressed as it passes deep to the bicipital aponeurosis (Figs 16.2A and B).

The ***brachial artery*** is centrally placed in the fossa and divides into the radial and ulnar arteries. Its immediate anterior relation is the bicipital aponeurosis. Overlying the aponeurosis are the fasciae, median cubital vein and skin. Posteriorly the artery rests on the floor, the brachialis muscle which separates it from the elbow joint. The radial artery, which is a terminal branch of the brachial artery, passes under cover of brachioradialis and runs downwards to reach the apex of the fossa. The ulnar artery, which is the

Dissection

The skin incisions made for exposure of the front of arm or front of forearm would have also exposed the cubital fossa. If an isolated cubital fossa dissection is carried out, make the vertical incision in the middle of the anterior aspect of the upper limb and the two transverse incisions at its two ends as described for the exposure of front of arm.

Identify and define the superficial veins, especially the median cubital vein. Open the deep fascia to expose the cubital fossa clearly.

Identify and define the boundaries of cubital fossa. Locate the inserting tendon of the biceps and trace it to its attachment. Locate the bicipital aponeurosis. After studying the aponeurosis, cut it transversely by placing a limb of the forceps underneath so as to prevent injury to deeper lying brachial artery. Once the aponeurosis is cut, the brachial artery comes into view. See and study its termination. Trace the branches as much as possible. Locate the median nerve and trace it. See that the nerve passes between the two heads of pronator teres. Study and review the contents of the fossa.

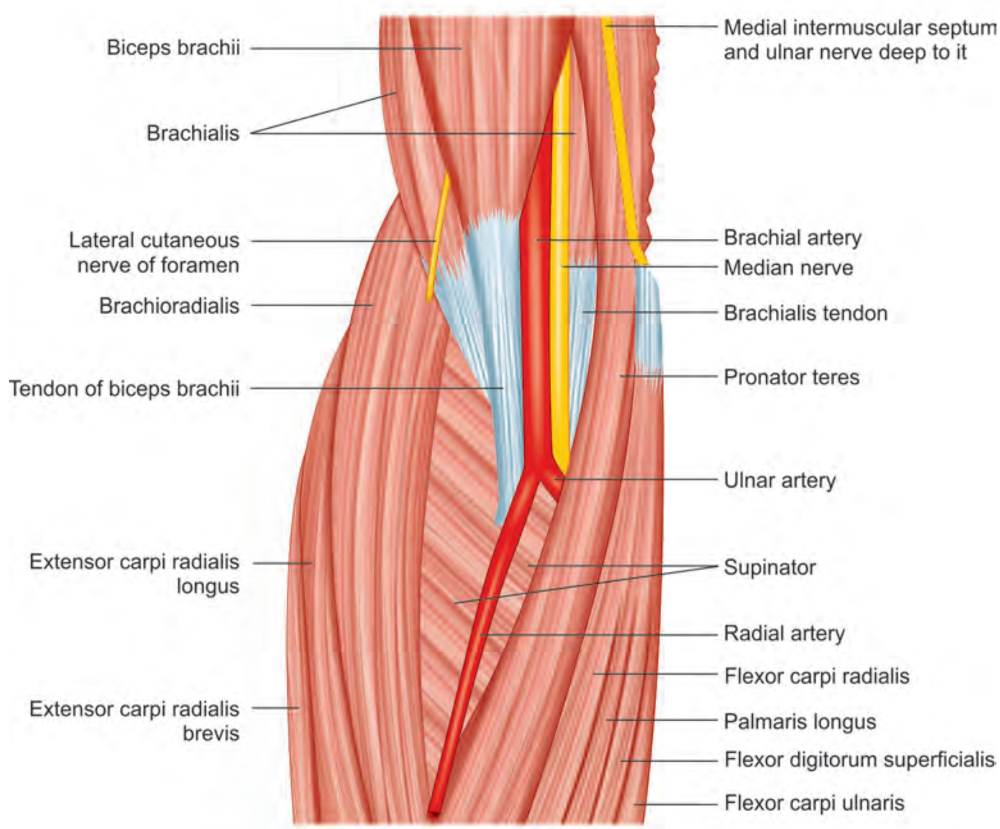


Fig. 16.2A: Cubital fossa seen after removal of superficial structures

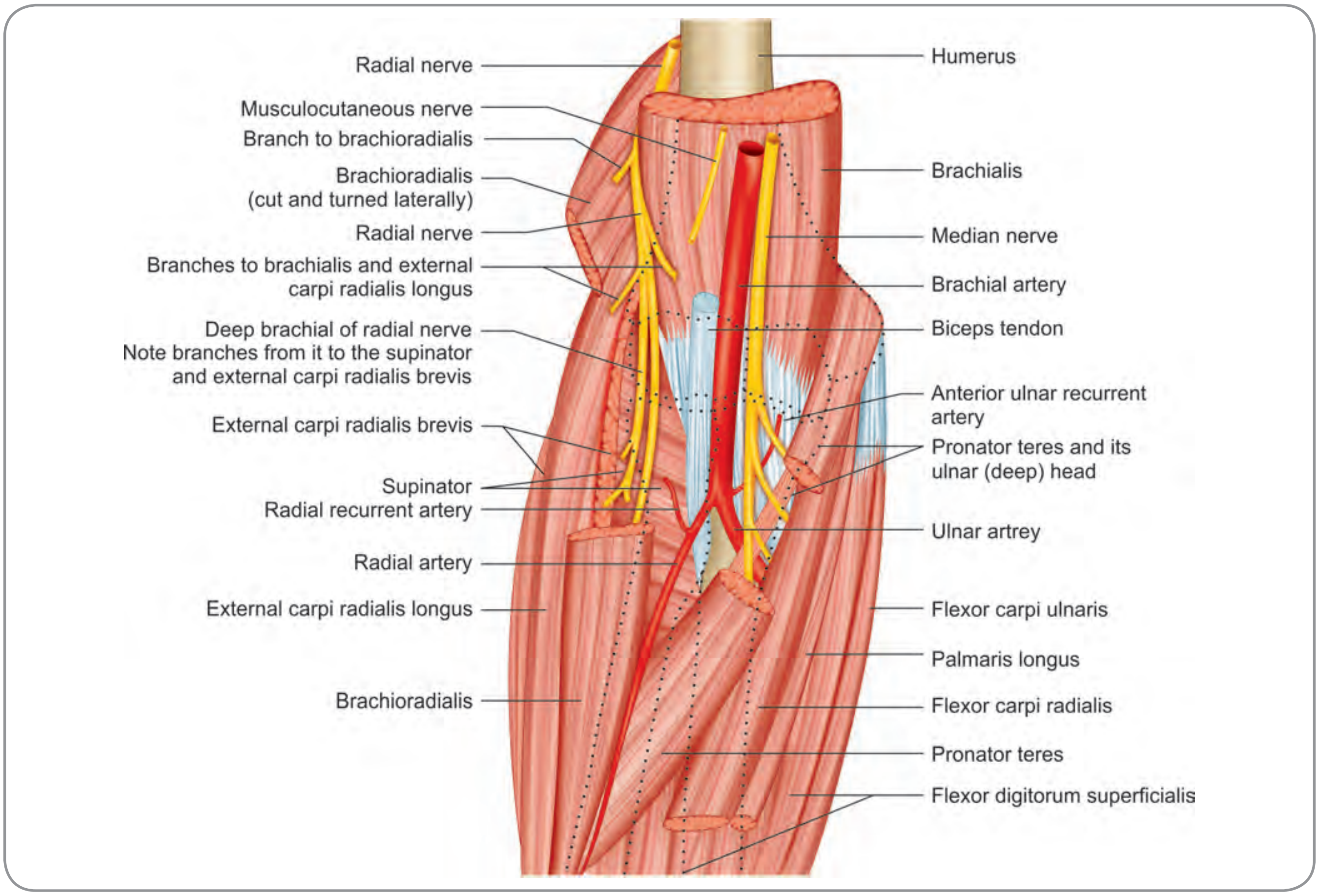


Fig. 16.2B: Cubital fossa. Segments of some muscles have been removed to reveal deeper structures

other terminal branch, passes ***deep to*** the deep head of the pronator teres. The deep head separates the median nerve from the ulnar artery.

The ***radial nerve*** enters the cubital region by passing forwards in the interval between the brachialis (medially) and the brachioradialis (laterally). Here it gives branches to both these muscles and also to the extensor carpi radialis longus. The radial nerve then divides into superficial and deep branches. The superficial branch descends into the front of forearm. The deep branch (otherwise called the posterior interosseus nerve) enters the substance of the supinator muscle and (while within the muscle) winds around the radius to reach the back of forearm.

Apart from the abovementioned structures, parts of the radial recurrent artery, anterior ulnar recurrent artery and the ulnar collateral artery may be seen in the cubital fossa. The musculocutaneous nerve can be seen at the lateral border of the tendon of biceps from where it continues as the lateral cutaneous nerve of forearm. A few lymph nodes may be found near the bifurcation of the brachial artery and are estranged members of the supratrochlear group of nodes They receive afferents from the surrounding tissues and their efferents pass along the venae comitantes of the brachial artery to join the deep lymph vessels.

Variations in the Superficial Venous Pattern

The superficial veins of the upper limb show considerable variation, especially in the cubital region. The most common pattern is the presence of a ***median cubital vein*** that connects the cephalic and the basilic veins. This vein, when present, runs upwards and medially from the cephalic (in the forearm) to the basilic (in the arm). The direction of drainage, is therefore, from superficial to deep.

In more than one-fifth of the general population, a ***median antebrachial vein*** (median vein of forearm) can be seen. This vein is formed at the base of the thumb by the joining of several smaller superficial veins. It curves around the lateral side, ascends up the forearm in the middle of the anterior aspect and as it approaches the cubital fossa, divides into two divisions. The medial division is the median basilic vein that joins the basilic vein in the arm and the lateral division is the median cephalic vein that joins the cephalic vein in the arm. This formation leads to the M pattern of superficial veins.

Whatever the case may be, the median cubital vein or the median basilic vein crosses superficial to the bicipital aponeurosis which separates the vein from the underlying brachial artery.

Clinical Correlation

- The superficial veins of the upper limb are easily and usually accessed in the cubital fossa. The veins are prominent and can be seen clearly. In the most common pattern of superficial veins, the median cubital vein lies across the fossa, lying directly on the deep fascia and the bicipital aponeurosis and coursing diagonally from the cephalic vein of the forearm to the basilic vein of the arm. Thus, the vein runs upwards and medially. It is the vein that is usually approached for intravenous injections and blood transfusion. The bicipital aponeurosis provides anchorage to the vein and separates it from the underlying brachial artery. The median cubital vein may also be used for cardiac catheterization and angiographic procedures.
- Blood pressure of an individual is recorded usually by auscultating the brachial artery in the cubital fossa.
- ***Bicipital aponeurosis***, though not very strong, affords protection to the underlying brachial artery. This factor has some degree of significance in venipuncture procedures involving the median cubital vein. The artery is kept under cover and protected from accidental injuries by the venous needles. Of the several epithets given to the bicipital aponeurosis – semilunar fascia, because of its crescentic shape; bicipital fascia, because of its muscle of origin; lacertus fibrosus, because of it being a fibrous band from a muscle – one is of historical and functional significance. It is (was) called the ***grace Deux tendon*** (tendon of divine grace) During olden times, venous blood letting was practised as a method of treatment for several disorders. The median cubital vein was the preferred site. The bicipital aponeurosis prevented the brachial artery from being cut during the blood letting thus preventing (dangerous and more complicated) arterial bleeding.
- The ***biceps jerk*** (bicipital myotatic reflex jerk) is often elicited by tapping the biceps tendon in the cubital fossa.

The cubital region is the region of the elbow. The elbow joint and the cubital fossa are the major features of this region. Certain important points regarding the applied anatomy of structures around this region are worth remembering.

PRONATOR ENTRAPMENT SYNDROME

The median nerve can be entrapped, in the elbow region, at four different sites. An entrapment neuropathy will result.

- ***Under the ligament of struthers:*** This ligament, if present, connects a supracondyloid spur of the medial condyle of the humerus to the pronator teres muscle. When the ligament is present, the median nerve passes under it. The nerve can be compressed here.
- ***Under the bicipital aponeurosis:*** While the nerve is travelling under the aponeurosis in the cubital fossa, it may be compressed.
- ***Between the two heads of pronator teres muscle:*** The nerve passes between the two heads of pronator teres to reach the forearm. It may either be compressed by the aponeurotic fibres of the superficial head or rubbed against the sharp aponeurotic edge of the deep edge, the effects of both being the same.
- ***Under the fibrous edge of flexor digitorum superficialis:*** The nerve may be compressed here.

The resultant effects of nerve compression are the same in all cases. There will be pain on the ventral aspect of distal arm and proximal forearm. However, pain is aggravated by varied movements depending upon the cause. Flexion of elbow, pronation or flexion of middle finger may aggravate. Surgical decompression may be required in severe cases.

CUBITAL TUNNEL SYNDROME

The humeral and ulnar heads of flexor carpi ulnaris are connected by a tendinous arch. The tunnel formed by this arch is called the cubital tunnel. The ulnar nerve which passes through the tunnel may be compressed resulting in the condition called 'cubital tunnel syndrome'. Pain in the medial aspect of proximal forearm, paraesthesia and numbness in the ulnar 1½ fingers and ulnar side of the dorsum of hand are the symptoms. They are worsened by elbow flexion. Weakness of muscles supplied by the ulnar nerve may also occur. However, due to sparing of the flexor carpi ulnaris and flexor digitorum profundus fibres, clawing does not happen in this syndrome.

ULNAR NERVE DAMAGE AT THE ELBOW

The ulnar nerve is prone to injuries and damages as it passes posterior to the medial epicondyle. In this location, it is covered only by skin and fasciae. During complete flexion of the elbow, the nerve becomes more prominent than the bony prominences of medial epicondyle and olecranon. The nerve is easily damaged. Muscles supplied by the ulnar nerve are paralysed or weakened.

Multiple Choice Questions

1. The medial boundary of the cubital fossa is formed by:
   a. The medial margin of pronator teres
   b. The lateral margin of pronator teres
   c. The medial margin of brachioradialis
   d. The lateral margin of brachioradialis

2. Medial to the brachial artery in the cubital fossa is:
   a. Posterior interosseous nerve
   b. Bicipital tendon
   c. Median nerve
   d. Radial nerve

3. The floor of the cubital fossa is formed by:
   a. Brachioradialis and supinator
   b Brachialis and supinator
   c. Brachialis and biceps brachii
   d. Brachioradialis and biceps brachii

4. The median cubital vein connects the:
   a. Brachial veins and the basilic vein
   b. Axillary vein and the cephalic vein
   c. Cephalic vein and the basilic vein
   d. Cephalic vein and the median cephalic vein

5. In the cubital fossa, the median nerve can be compressed by:
   a. Struther's ligament
   b. Bicipital aponeurosis
   c. Brachial artery
   d. Arch forming cubital tunnel

ANSWERS

1. b **2.** c **3.** b **4.** c **5.** b

Clinical Problem-solving

Case Study 1: A 45 year-old man had to be investigated. The laboratory technician applied a tourniquet to the patient's arm and made the veins prominent.

- ❑ What investigation/procedure was the technician planning?
- ❑ In what way are the veins of the cubital fossa significant in such a procedure?
- ❑ For what other purposes can these veins be used?

Case Study 2: You were being asked to record the blood pressure of an individual in your physiology class.

- ❑ Which artery do you readily access to record blood pressure of an individual?
- ❑ What is the reason that this artery at this location is preferred?
- ❑ What structure affords protection to the artery?

(For solutions see Appendix).

Chapter 17

Forearm and Hand

Frequently Asked Questions

- Discuss the long flexors of the fingers in detail with regard to their attachments, tendons, nerve supply and actions.
- Write detailed notes on (a) Pronator teres, (b) Flexor carpi radialis, (c) Flexor carpi ulnaris, (d) Palmaris longus, (e) Flexor pollicis longus, (f) Pronator quadratus.
- Write notes on (a) Insertion of long flexors, (b) Palmar aponeurosis, (c) Vincula, (d) Panniculosus carnosus.
- Briefly describe (a) Flexor retinaculum, (b) Fibrous flexor sheath, (c) Ulnar bursa, (d) Radial bursa (e) Palmaris brevis, (f) Lumbricals, (g) Interossei, (h) Movements of the thumb.
- Write notes on (a) Thenar muscles, (b) Hypothenar muscles, (c) Adductor pollicis, (d) Extensor indicis, (e) Extensor carpi radialis longus and extensor carpi radialis brevis, (f) Extensor apparatus.
- Discuss the following: (a) Writing position, (b) Brachioradialis, (c) Outcropping muscles, (d) Anatomical snuff box, (e) Extensor expansion.
- Write notes on (a) Superficial palmar arch, (b) Deep palmar arch, (c) Princeps pollicis artery, (d) Radial pulse, (e) Carpal rete.
- Discuss the carpal tunnel syndrome in detail.
- Write detailed notes on (a) Carpal tunnel, (b) Cubital tunnel syndrome, (c) Posterior interosseous nerve.

The forearm is the distal unit of the articulated ensemble of the upper limb and is the region between the elbow and the wrist. It contains two bones, the radius and the ulna which are joined by an interosseous membrane. The forearm plays a major role in assisting the shoulder to focus power of movements and in placing the hand in the correct position.

The forearm is subdivided into two compartments—the flexor and the extensor. Muscles of similar purpose and innervations are grouped in the same compartment. The interosseous membrane acts as a kind of partition; the flexor compartment lies anterior to this membrane and includes the pronators; the extensor compartment lies posterior and includes the supinators. The anterior compartment communicates with the palm through the carpal tunnel.

Seventeen muscles cross the elbow joint. Only a few of them act exclusively on the elbow joint; many of them act on the wrist, hand and fingers. In order to act at distant locations, many of these muscles have long tendons However, since the wrist, hand and fingers need to have a wide range of motions, these muscles will have to be powerful; therefore, they have large fleshy portions. The forearm, thus accommodates muscles which are both bulky and tendinous. It can also be noted that the muscles of forearm take origin from the distal end of humerus. Due to this fact, the distal end of the arm becomes a functional part of the forearm.

The flexor muscles of forearm are twice stronger and bulkier than the extensor muscles.

Though separate entities can be technically defined, it is preferable to consider the wrist and the hand along with the forearm because of their functional harmony.

The 'hand' is the distal most part of the upper l mb comprising the working elements of the metacarpus and the digits The 'wrist' is the junction between the forearm and the hand. Movements of the hand and digits occur due to various adaptations at the wrist; movements at the wrist occur in conformity with movements of forearm, especially with those of supination and pronation.

To assist functional harmony, structures in the forearm, wrist and hand are interconnected to each other; many of them work in unison and therefore, are described and studied together. The tendons of the flexor muscles of forearm continue into the palm and the palmar aspects of digits; the tendons of the extensor muscles continue into the dorsum and he dorsal aspects of digits.

NOTABLE FEATURES OF PALMAR SKIN

- The palmar skin is adapted for gripping and grasping; it is thick and rests on a dense but pliable layer of fat.
- It is abundant in sweat glands
- It is anchored to the deep fascia by fibrous bands; this anchoring prevents the palmar skin from being stripped off like a loose glove during various movements of the hand. These fibrous bands are more in the pads of fingers, along the sides of fingers and in the middle of the palm.
- Due to the presence of the fibrous bands, the fat of the superficial fascia is partitioned off in loculi
- The palmar skin, as can readily be seen, is corrugated; that is, it is thrown into folds, thus creating ridges and furrows. This corrugation helps in 'gripping'. Sweat glands open on the ridges. The ridges (and therefore, the furrows too) make varying patterns. The patterns on the pads of fingers are disposed in the form of arches, loops and whorls. These patterns are specific to an individual; the spacing of the openings of the sweat glands, their sizes and shapes are also specific. The impression created by the patterns of ridges and openings of sweat glands give rise to 'finger prints'; finger prints can be recorded and studied.
- To aid further in the gripping mechanism, the palmar skin lacks the sebaceous glands (which tend to secrete a slippery sebum).
- The palmar skin has permanent skin creases called the 'flexure lines' (the lines of palmistry). There is no fat at these creases and the skin is firmly fixed to the underlying fascia. The creases help in flexion and opposition movements of the fingers. Though several of them are seen, some of them are prominent and almost permanent in position. Two transverse creases and one longitudinal crease are well marked on the palm; the proximal transverse palmar crease (head line) is more or less in the middle of the palm; the distal transverse palmar crease (heart line) is immediately proximal to the metacarpophalangeal joints. The major longitudinal palmar crease (also called the thenar crease) starts along with or close to the proximal transverse crease and circles around the thenar eminence to reach the distal carpal crease. Two other minor longitudinal creases may also be present—the median (on the midline of palm) and the ulnar (on the base of hypothenar eminence). There are two or three transverse creases across the wrist. The most distal of them (distal carpal crease) is slightly convex towards the palm. The creases on the digits are also transverse. The creases at the roots of he digits (or the palmar digital creases) are about 2 cm distal to the metacarpophalangeal joints.

Clinical Correlation

- The palmar creases develop during the 12th week of intrauterine development. Changes in the normal pattern of creases indicate disorders in development of the embryo.
- Single palmar creases (formerly called simian creases) are associated with several developmental anomalies including Down's syndrome, Turner's syndrome, Klinefelter's syndrome and Trisomy 16.
- Dermatoglyphics (Greek.derma=skin, Greek. Glyphe= carving) is the scientific study of the ridge pattern of the hand. It can be applied in studies concerning genetic disorders.

FASCIAE IN FOREARM AND HAND

Both superficial and deep fasciae are present in the forearm and hand. Both undergo certain specialised modifications in certain areas to satisfy functional demands

- ***Superficial fascia:*** In the forearm, the superficial fascia has no special features. It is thin and has minimal fat. On the dorsum of the hand, it is thin and loose. In the palm, the superficial fascia is thick, laden with fat and forms dense pads which protect underlying structures and also provide buffer for efficient grip. In the middle of the palm, it is comparatively thinner but its fibrous strands are densely packed. In the thenar, hypothenar and metacarpophalangeal regions, it is thicker, less fibrous but more fatty and forms pads which provide adequate cushioning during gripping and grasping. Along the lines of flexure (commonly called the flexure lines), it is densely fibrous and connects the skin to the underlying deep fascia.

  In the distal part of the palm, the superficial fascia is thickened to form the superficial transverse metacarpal ligament. This is a band of transverse fibres which connects the palmar surfaces of the fibrous flexor sheaths in the region of the webs of fingers.

  In the digits, the superficial fascia is thin but holds the various neurovascular structures of the digits.
- ***Deep fascia:*** The deep fascia of the forearm is continuous superiorly with the deep fascia of the arm and inferiorly with that of the hand. Though it is present all around the forearm it does not form a discernible sleeve as in the thigh. The muscles of the human forearm are adapted for refined, repetitive and rapid movements; presence of a dense sleeve of fibrous deep fascia would impede such movements and constrict the muscles; the deep fascia of the forearm, therefore, is not a sleeve (in the lower limb, the muscles are bulky and are adapted for powerful locomotor movements; presence of a dense sleeve would assist retaining the muscles in shape and position lest they fall flabby due to their bulkiness and gravity).

  In the proximal part of the forearm, the deep fascia receives reinforcements, anteriorly from the bicipital

aponeurosis, posteriorly from the tendinous insertions of triceps and medially and laterally from the common flexor and extensor origin fibres respectively. Throughout the length of the forearm, it is attached to the posterior border of ulna. On the anterior aspect, it blends with the fascia covering the flexor digitorum superficialis.

On the dorsal aspect of the wrist, the deep fascia forms the extensor retinaculum and on the anterior aspect of the carpus, it condenses to form the flexor retinaculum.

In the hand , the deep fascia is in two layers, both in the palmar and dorsal aspects. On the palm, the superficial layer thickens in the centre to form the palmar aponeurosis; over the thenar and hypothenar areas, it forms thin sheaths. The deep layer covers the adductor pollicis muscle and the in erossei muscles. In the gap between metacarpal heads, a few fibrous strands interconnect the two layers. On the dorsal aspect, the thin superficial layer stretches from the distal border of the extensor retinaculum to the bases of fingers where it blends with the extensor tendons. The deep layer clothes the interossei muscles and merges with the superficial layer at the clefts of the fingers.

In the digits, the deep fascia forms the fibrous flexor sheaths on the palmar aspect; it remains thin and blended with the extensor tendons on the dorsal aspect.

Added Information

The deep fascia covering the flexor muscles of the forearm receives reinforcement from the tendon of biceps brachii. This is the bicipital aponeurosis. Similarly, the fascia covering the extensors also receives reinforcement from the tendon of triceps. This may well be called the ***tricipital aponeurosis***.

Evolutionary Morphology

Anatomically, the upper or proximal limit of the forearm is the elbow joint; however, functionally the forearm includes the distal arm too. Hand, wrist and distal forearm have to move across a wide range of dimensions. To increase this functionality, their 'bulk' should be less. But, they also need 'power' which will be provided by the muscles. Small and intricate movements expected to be performed by wrist and hand (including fingers) do need separate and specialised muscles. In o der to have the best advantage, the muscles are placed at a distance from the wrist and hand with the power and function being conveyed through long tendons. Proximal forearm alone is not sufficient for all the muscles to be placed; so, the proximal attachments of these muscles are provided by the humerus, thus functionally including the distal arm in forearm. The humerus, in an effort to provide additional space for the forearm muscles, develops medial and lateral extensions in the form of medial and lateral epicondyles and supracondylar ridges. The extensions could not have occurred directly anterior and posterior for such direct extensions would have interfered with upper limb movements. The flexors come to be attached to the medial extension and the extensors to the lateral extension. This causes a 'spiral' effect; the anterior compartment is truly anteromedial and the posterior compartment is truly posterolateral.

ANTERIOR COMPARTMENT OF FOREARM AND PALM OF HAND

The anterior compartment of forearm lies in front of the radius, ulna and the interosseous membrane. It is served mainly by the median nerve with a small contribution from the ulnar nerve. Many muscles of this compartment take origin from the medial epicondyle and the medial supracondylar ridge of the humerus and so the compartment is anteroedial in the proximal part of the forearm and truly 'anterior' in the distal forearm only. The tendons of these muscles continue into the palm and the palmar aspects of the fingers.

Though there is functional continuity and harmony between the muscles of the anterior forearm and the palm, they are described separately for the sake of convenience.

MUSCLES OF THE ANTERIOR COMPARTMENT OF FOREARM (TABLE 17.1)

The muscles of the anterior compartment of forearm (front of forearm or anterior antebrachial compartment) are the flexor–pronator muscles and are arranged in three layers:

1. ***Superficial layer***
   - Pronator teres
   - Flexor carpi radialis

Dissection

With the cadaver in the supine position, abduct the upper limb so that it is placed outstretched at right angles to the trunk. Tie the limb to a wooden plank keeping the forearm supine. Make a longitudinal incision on the midline of the flexor surface of the forearm, from the inferior angle of the cubital fossa to the wrist. After making horizontal incisions at the upper and lower limits of the longitudinal incision, slowly reflect the skin and superficial fascia. The two skin flaps can be reflected medially and laterally. Using a pair of scissors, slit the antebrachial fascia along the same longitudinal line. Using your fingers, slowly separate the antebrachial fascia from the underlying muscles. Four muscles of the superficial group are seen. Again using your fingers, separate these four muscles and identify their tendons. Trace the muscle bellies as much as possible to their origin. Then identify the flexor digitorum superficialis and trace it to the medial epicondyle of humerus. To see the flexor digitorum superficialis clearly, one or two of the superficial muscles have to be transected. Without removing any muscle piece, slowly and carefully transect the required muscles and see the flexor digitorum superficialis.

See the attachments of the muscle to humerus, ulna and radius. Identify the tendinous arch of the muscle and the ulnar artery and the median nerve passing under the arch. Trace the tendons of this muscle distally and see that the median nerve lies lateral to them and the ulnar artery and nerve lie medial to them. Locate the radial and the ulnar arteries. Clean and define them. Without damaging their branches, study their course.

Table 17.1: Muscles of the anterior compartment of forearm

Muscle	Origin	Insertion	Action	Nerve supply
Pronator teres	• Humeral head from (a) lowest part of supracondylar and (b) medial epicondyle • Ulnar head (deep head) from medial side of coronoid process	Lateral surface of shaft of radius, at about its middle	• Pronates the forearm. • Weak flexor of elbow	Median nerve (C6 7)
Flexor carpi radialis	Medial epicondyle of humerus. The tendon passes through a tunnel bounded laterally by a groove in the trapezium, and medially by two slips of the flexor retinaculum	Palmar surface of base of second metacarpal bone. A slip reaches the third metacrapal bone	Flexion and abduction of wrist	Median nerve (C6, 7)
Flexor carpi ulnaris	• **Humeral head:** medial epicondyle. • **Ulnar head:** – Medial side of olecranon process – Upper two-thirds of posterior border • Tendinous arch passing from medial epicondyle to olecranon process.	Pisiform bone Pull is transmitted to the hamate bone through piso-hamate ligament and to the fifth metacarpal through the piso-metacarpal ligament	Flexion and adduction of wrist	Ulnar nerve (C7, 8)
Palmaris longus	Medial epicondyle of humerus	• Flexor retinaculum • Palmar aponeurosis	Flexion of hand at wrist makes palmar aponeurosis tense	Median nerve (C7, 8)
Flexor digitorum superficialis	• Humero-ulnar head from – Medial epicondyle of humerus – Ulnar collateral ligament of elbow joint • Radial head from anterior border of radius (oblique line)	Tendon splits into four parts, one for each digit except the thumb. Opposite the terminal phalanx the tendon for each digit splits to form two slips, medial and lateral. Each slip is inserted on the corresponding side of the middle phalanx.	Flexion of middle and proximal phalanges of digits concerned	Median nerve (C7, 8 T1)
Flexor digitorum profundus	• From following parts of ulna: – Medial surface of coronoid process – Upper three-fourths of anterior surface – Upper three-fourths of medial surface – Upper three-fourths of posterior border – Medial half of interosseus membrane	Tendon splits into four parts, one for each digit other than the thumb. The tendon for each digit is inserted into the base of the distal phalanx.	• Flexion of distal phalanges • Helps in flexing the wrist	• Medial part by ulnar nerve. • Lateral part by median nerve (ant. int. branch) (C8, T1)
Flexor pollicis longus	• Anterior surface of radius (below oblique line) (excluding lower one-fourth) • Lateral part of interosseus membrane • Occasionally slip from margin of coronoid process	Base of distal phalanx of thumb (ventral aspect)	Flexion of phalanges of thumb	Median nerve (ant. int. branch) (C8, T1)
Pronator quadratus	• Oblique ridge on lower part of anterior surface of ulna	• Anterior surface of shaft of radius in its lower one-fourth • Medial surface of radius (triangular area above ulnar notch)	• Chief pronator of the forearm • Prevents separation of radius and ulna	Median nerve (ant. int. branch) (C8, T1)

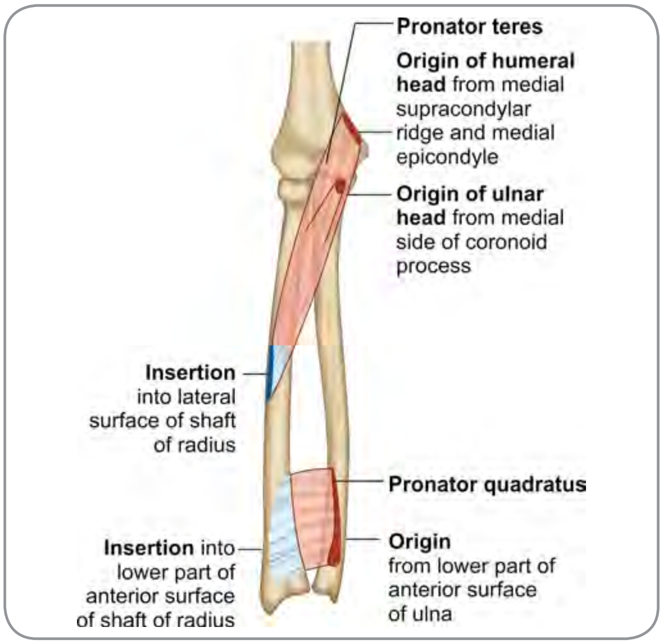


Fig. 17.1: Attachment of pronator teres and pronator quadratus muscles

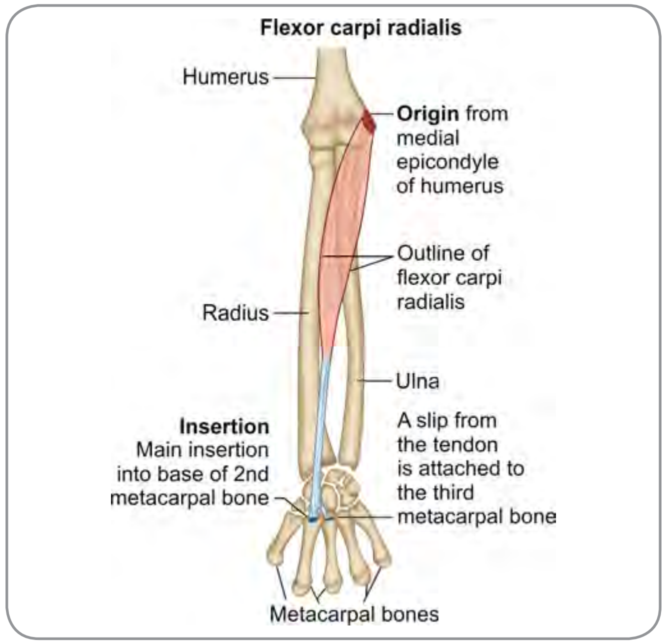


Fig. 17.2: Attachments of Flexor carpi radialis

- Flexor carpi ulnaris
- Palmaris longus

2. ***Intermediate layer***
   - Flexor digitorum superficialis
3. ***Deep layer***
   - Flexor digitorum profundus
   - Flexor pollicis longus
   - Pronator quadratus.

The superficial and intermediate layer muscles cross the elbow joint but the deep layer muscles do not do so.

Additional Notes on the Pronator Teres (Fig. 17.1)

- This is a fusiform muscle and is the lateral most of the superficial layer.
- Its insertion is at the site of maximum convexity of the shaft of the radius.
- The lateral border of pronator teres forms the medial boundary of the cubital fossa.
- The median nerve passes between the humeral and ulnar heads.
- The ulnar artery passes deep to the ulnar head. In other words, the ulnar head separates the ulnar artery from the median nerve.

Additional Notes on the Flexor Carpi Radialis (Fig. 17.2)

- This is a long fusiform muscle; in the middle of the forearm, its fleshy belly continues into a long tendon that passes anterior to the lateral part of the wrist.
- At the wrist, the tendon passes through a tunnel, bounded laterally by a groove in the trapezium, and medially by two slips of the flexor retinaculum that are attached to the margins of the groove. The tendon has its own synovial tendinous sheath.
- The radial artery lies immediately lateral to the tendon of this muscle (Fig. 17.3).

Additional Notes on the Flexor Carpi Ulnaris (Fig. 17.4)

- This is the medial most of the superficial layer of muscles.
- The ulnar nerve enters the forearm by passing deep to the tendinous arch connecting the humeral and ulnar heads of origin of this muscle.
- The flexor carpi ulnaris is completely innervated by the ulnar nerve.
- At the wrist, the ulnar artery and nerve lie lateral to the tendon of this muscle.

The flexor carpi radialis, if acting alone, produces flexion and abduction simultaneously at the wrist so that the hand moves anterolaterally; the flexor carpi ulnaris, if acting alone, produces flexion and adduction simultaneously at the wrist so that the hand moves anteromedially. When the

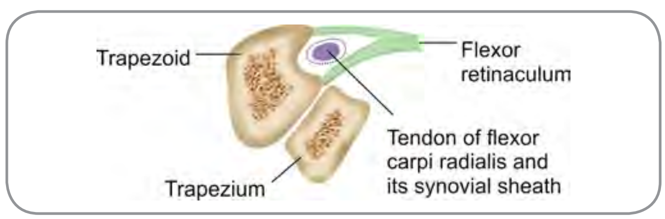
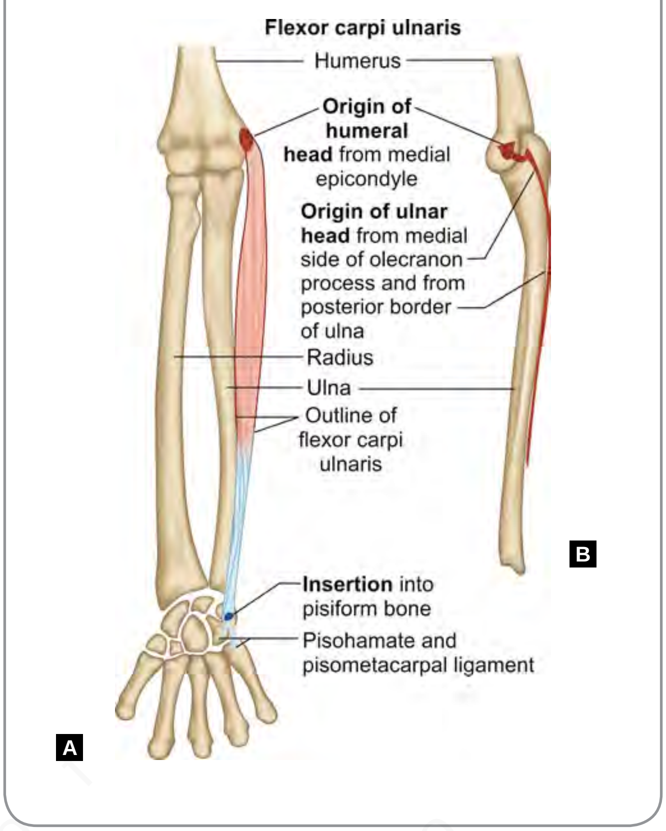


Fig. 17.3: Transverse section across the lateral part of the wr st showing the relationship of flexor carpi radialis tendon to the flexor retinaculum



Figs 17.4A and B: A. Attachments of flexor carpi ulnaris **B.** Humerus and ulna viewed from the medial side to show the origin of the ulnar head of the muscle

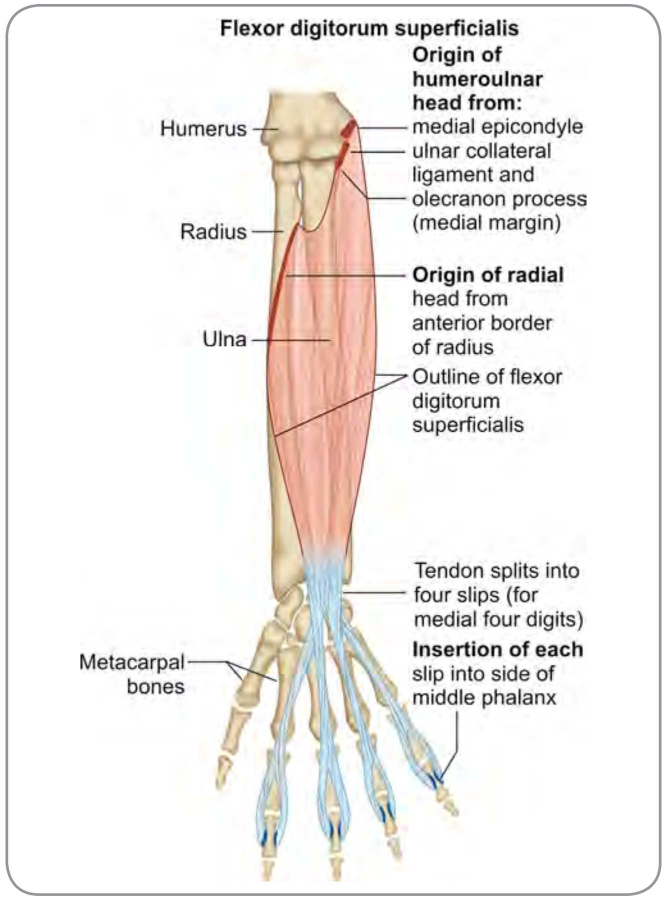


Fig. 17.5: Attachments of flexor digitorum superficialis

flexor carpi radialis and flexor carpi ulnaris act together, they produce flexion of the wrist. When the flexor carpi radialis and the extensor carpi radialis longus and brevis act together, abduction of the wrist is produced. When the flexor carpi ulnaris and the extensor carpi ulnaris act together, they produce adduction of the wrist.

Additional Notes on the Palmaris longus

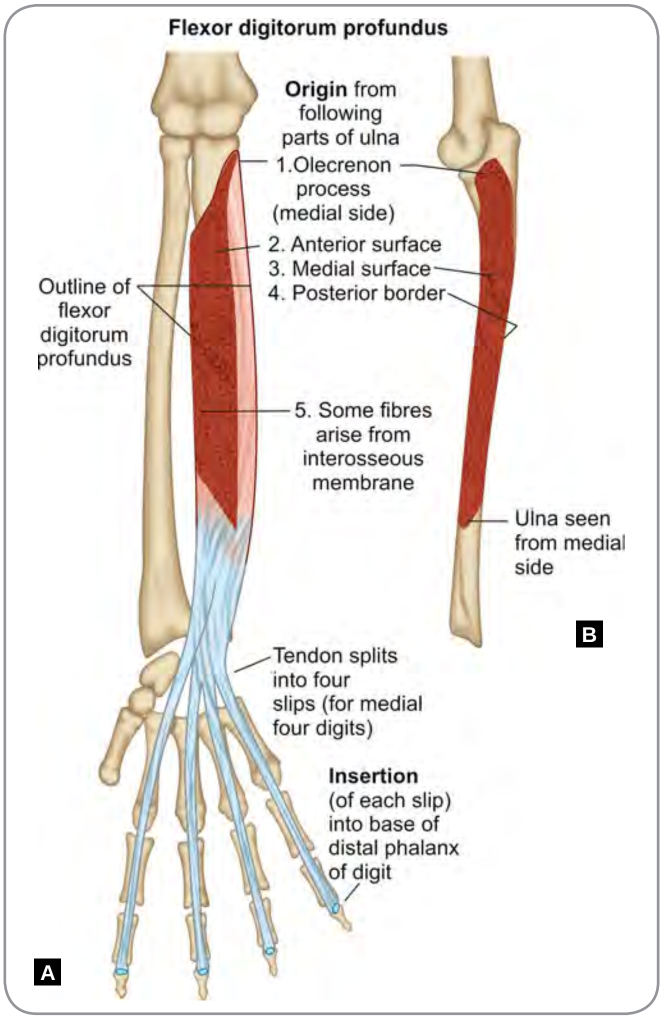
- This is a small fusiform muscle that may frequently be absent.
- The thin long tendon of this muscle lies medial to the median nerve at the wrist.

Additional Notes on the Flexor Digitorum Superficialis (Fig. 17.5)

- This muscle structurally forms an intermediate layer between the superficial and deep layers.
- The median nerve and the ulnar artery enter the forearm by passing between the humeroulnar and radial heads of this muscle.
- It divides into four tendons; the tendons for middle and ring fingers lie anterior to the tendons for index and little fingers.
- The muscle initially acts on the proximal interphalangeal joint and flexes the middle phalanx; its continued action causes movement at the metacarpophalangeal joint and the wrist joint resulting in flexion of the proximal phalanx and the wrist.
- The muscle can independently flex each finger that it sends tendon to.

Additional Notes on the Flexor Digitorum Profundus

- This is the only muscle that can flex the distal inter-phalangeal joints of the fingers.
- The fleshy part of the muscle covers the anterior aspect of the ulna in the forearm.
- Of the four parts into which the muscle divides, the part to the index finger separates from the rest, quite early in the lower forearm; this part is also capable of independent contraction thus making it possible for the index finger to flex independent of the other fingers.
- The profundus muscle flexes the distal interphalangeal joint after the superficialis muscle has flexed the proximal interphalangeal joint. Each of its tendon is, therefore, capable of acting on the two interphalangeal joints, the metacarpophalangeal joint and the wrist joint (Figs 17.6A and B).



Figs 17.6A and B: A. Attachments of flexor digitorum profundus **B.** Medial view of ulna to show area of origin of the muscle

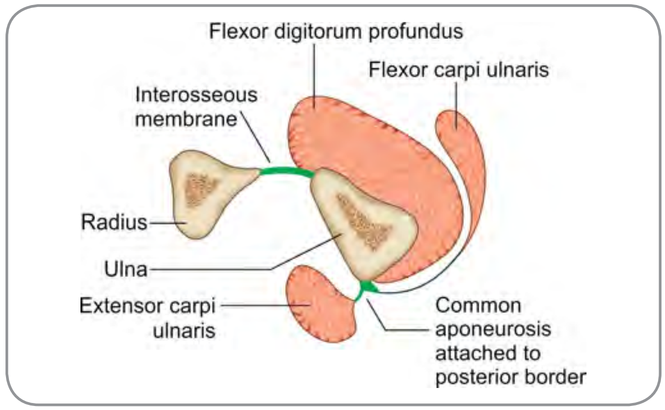


Fig. 17.7: Schematic section across radius and ulna to show muscles attached to the posterior border of ulna

The flexor digitorum superficialis gives rise to four tendons near the wrist. A little proximal to this, the flexor digitorum profundus divides into four tendons At the wrist the four tendons of the flexor digitorum superficialis lie superficial to the four tendons of the profundus. All the eight tendons pass through the ***carpal tunnel*** which is bounded, in front by the flexor retinaculum; and behind by the carpal bones. Over the base of the proximal phalanx the profundus tendon lies deep to that of the superficialis. Over the middle of the proximal phalanx the superficialis tendon splits into two slips The profundus tendon passes through the interval between these slips (Fig. 17.7).

During their course over the ventral aspect of the digits the tendons of the flexor digitorum superficialis and profundus (for that digit) lie in a common canal bounded posteriorly by the phalanges and anteriorly (and on the sides) by a fibrous sheet. This sheet is called the fibrous flexor sheath. It holds the tendons in place

When the tendons of superficialis and profundus pass through the carpal tunnel, they are enclosed in a common synovial sheath called the ulnar bursa

Insertion of long flexor tendons: Both flexor digitorum superficialis and flexor digitorum profundus divide into four tendons each to the medial four digits. In the middle of the palm, the pair of tendons (one superficialis and one profundus tendon) to a particular digit runs distally towards the digit under cover of palmar aponeurosis. The pair then emerges from under cover of the corresponding slip of the palmar aponeurosis. Anterior to the head of the metacarpal, the pair enters into the fibrous flexor sheath of the corresponding digit. Anterior to the proximal phalanx, the superficialis tendon splits into two and the two split portions spread out like the letter 'V'. The profundus tendon passes distally through the opening created between the limbs of the 'V'. The central fibres of the split portions get attached to the corresponding half of the proximal margin of the middle phalanx. The side fibres of the split portions embrace the profundus tendon, pass around it and decussate dorsal to it. When they wrap around, the fibres reverse their surfaces; therefore, the anterior surface becomes posterior and the posterior surface becomes anterior. Thus a fibrous bed is formed for the profundus tendon. When the two slips unite, some fibres from both s de criss-cross; the structure appears like a crossing of fibres and is called the ***tendinous chiasm*** or the ***chiasma of Camper***. The fibres of the united portion then get attached to the sides of the anterior aspect of the middle phalanx The profundus tendon reaches the base of the distal phalanx to be inserted to the latter.

Dissection

For proceeding with the deep layer of the flexors of the forearm, transect the flexor digitorum superficialis at its middle. Reflect the two parts above and below. The median nerve is exposed now. Confirm the origin and course of the radial and ulnar arteries. Study the median nerve and its branches. Gradually probing with your fingers, identify the common interosseous artery and its branches. Trace the anterior interosseous artery and its branches. Turn your attention to the deep layer of muscles. Slowly retract the flexor digitorum profundus and the flexor pollicis longus muscles to expose the pronator quadratus. Study the muscles and the interosseous membrane which is seen still deeper.

Additional Notes on the Flexor Pollicis Longus (Fig. 17.8)

- Lying lateral to the flexor digitorum profundus, this muscle clothes the anterior aspect of the radius in the forearm.
- It ends in a tendon which runs across the lateral part of the front of the wrist.
- As the tendon runs through the carpal tunnel to reach the thumb, it is surrounded by a synovial sheath and a fibrous flexor sheath, just like the tendons of the long flexors of the digits. The synovial sheath surrounding this tendon is called the ***radial bursa*** and extends up to the insertion of the tendon.
- In the carpal tunnel, the radial bursa may communicate with the ulnar bursa.
- The muscle primarily acts on the interphalangeal joint of the thumb producing flexion; secondarily, it produces flexion at the metacarpophalangeal and carpometacarpal joints of the thumb and also at the wrist.

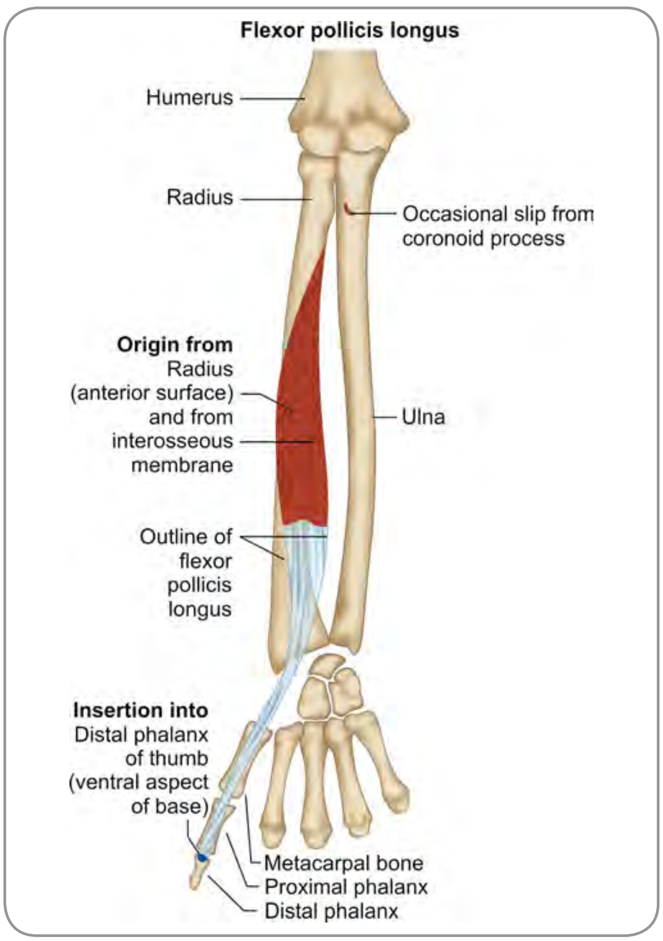


Fig. 17.8: Attachments of flexor pol icis longus

Additional Notes on the Pronator Quadratus

- This is the deepest muscle in the anterior compartment of the forearm and is quadrangular in shape, as the name suggests (Fig. 17.1).
- It covers the anterior aspects of the distal parts of the radius and ulna and also the interosseous membrane.
- It is the prime mover for pronation and so initiates the movement. Slow and sustained pronation is effected by this muscle. Rapid and powerful pronation is produced by pronator teres.
- Its action of retaining the bones of the forearm in position comes into play especially when upward thrust is transmitted through the wrist and the radius (separation of the bones can happen when such a th ust dislocates the radius).

Added Information

- The tendinous arch connecting the humeral and ulnar heads of the flexor carpi ulnaris is called the cubital tunnel.
- The flexor digitorum superficialis and flexor digitorum profundus (together called the long flexors of the digits) flex the metacarpophalangeal and the wrist joints.
- The profundus muscle produces slow and sustained action. The superficialis plays a significant role when speed is required. Similarly, when the fingers have to be flexed against resistance, it is superficialis that contributes more.
- When the wrist is simultaneously flexed with flexion of the metacarpophalangeal and interphalangeal joints, the long flexors operate over a shortened distance and so, their action becomes less powerful. In such a circumstance, it can be noticed that the flexion of fingers is weak. The fingers can also not be maintained in flexion. The operating distance of the long flexors is increased if the wrist is extended and their contraction becomes stronger. Palmar grip is more powerful if the wrist is extended. This fact is used in martial arts where the exponents are taught to forcibly flex the wrist of the opponent.
- The five tendons (four of flexor digitorum profundus and one of flexor pollicis longus) converge towards the midline of the forearm to enter the carpal tunnel. In lower animals, it is a single muscle that gives rise to five tendons to the five digits; in humans, flexor pollicis longus is a separate muscle and the deep flexor tendon to the index finger acquires some amount of independence in accordance with functionality.
- Flexor digitorum superficialis is developmentally a delaminated portion of the deep flexors.

Clinical Correlation

- ***Pronator syndrome:*** This is a condition of nerve entrapment syndrome. The median nerve is compressed between the heads of pronator teres either due to trauma or muscular hypertrophy or fibrous bands. Pain in the anterior aspect of the proximal forearm and altered sensations on the palmar aspects of the lateral three and half-fingers and corresponding area of palm are the usual symptoms The symptoms increase when there is repeated pronation

contd...

Clinical Correlation *contd...*

- The ulnar nerve which passes under the cubital tunnel may also be compressed. This ulnar nerve entrapment is called the ***cubital tunnel syndrome.***
- ***Testing the pronator teres:*** The forearm is flexed at the elbow and pronated from supine position, both against resistance. A normal muscle can be palpated at the medial border of the cubital fossa.
- ***Testing the flexor carpi radialis:*** The wrist is flexed against resistance. The muscle if normal, can be felt.
- ***Testing the flexor carpi ulnaris:*** The wrist is flexed against resistance. The muscle can be felt, if it is normal.
- ***Testing the palmaris longus:*** The wrist is flexed; thumb and little finger are tightly pinched against each other. The thin tendon of palmaris longus can be felt immediately proximal to the wrist.
- ***Testing the flexor digitorum superficialis:*** As each of the medial four fingers is examined, the other three are held in extension (to inactivate the profundus muscle); the finger that is tested for is flexed against resistance.
- ***Testing the flexor digitorum profundus:*** The proximal interphalangeal joint is held in an extended position while the individual attempts to flex the distal joint.
- A rounded swelling is sometimes seen on the back of the wrist. Though called a ***ganglion,*** the swelling is really a cyst walled by synovial membrane; the cyst is filled by fluid. The swelling is often in close relationship to the synovial sheath of a tendon and may be in communication with the latter. The cause for such a cyst is not known. The insertion of the tendon of extensor carpi radialis brevis is a common site for a ganglion.
- Inflammation of the synovial sheath surrounding the tendon may occur; this condition is called ***tenosynovitis*** (inflammation of the tendon sheath; teno=tendon, syno=synovial, itis=inflammation). If exudation occurs, pus accumulates in the synovial cavity. When such accumulation is large, the delicate arteries supplying the tendons are likely to be compressed leading to cessation of blood flow to the tendons. The tendons then may undergo avascular necrosis.
- The flexor compartment of the forearm is marked off from the extensor compartment by the medial and lateral margins. The medial margin runs along the olecranon and the posterior border of the ulna; the lateral margin runs along the insertions of brachialis, biceps, pronator teres and brachioradialis. These two margins are not crossed by any motor nerve; so, they are called internervous lines (meaning they are intermediary lines between territories of two motor nerves). Exploration of deeper structures can be done along these lines without any worry of damaging any nerve. The posterior border of ulna marks the internervous line between the motor territories of ulnar and radial nerves. The course of radial artery indicates the internervous line between the median and radial nerves.
- The flexor tendons may be severed in traumatic injuries of the distal forearm. They may be repaired by tendon grafting. The tendon of palmaris longus is the preferred choice for tendon grafting due to its length.

SPECIALISED FASCIAE OF ANTERIOR WRIST AND PALM

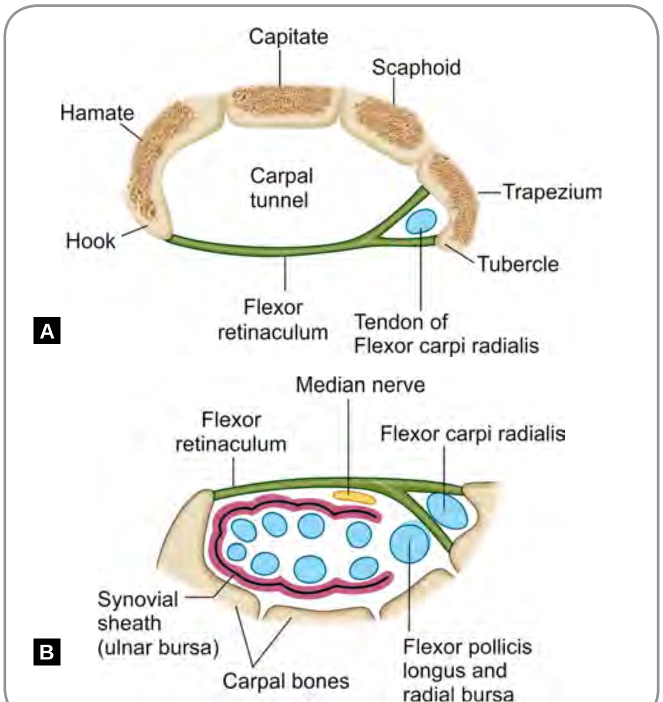
The deep fascia of the anterior wrist and palm is specialised to form—the flexor retinaculum, palmar aponeurosis and the fibrous flexor sheaths.

Flexor Retinaculum

Other name: Transverse carpal ligament.

This is a strong band of fascia stretching across the ventral aspect of the carpus. The space between the retinaculum and the carpal bones is called the ***carpal tunnel***. It transmits the tendons of the flexor digitorum superficialis and profundus, the tendon of the flexor pollicis longus and the median nerve (Figs 17.9A and B).

Measuring about 2.5 cm both in length and breadth, the retinaculum is continuous above and below with the deep fascia of the forearm and palm respectively. It is attached medially to the pisiform and the hook of hamate. Laterally, it splits into a superficial and a deep layer. The superficial layer gets attached to the tubercle of the scaphoid and to the anterior lip of a groove on the anterior aspect of trapezium. The deep layer is attached to the posterior lip of the groove. Thus, the groove on trapezium is converted into a tunnel for the tendon of flexor carpi radialis (Fig. 17.10).



Figs 17.9A to B: A. Boundaries of the carpal tunnel **B.** Structures passing through the carpal tunnel

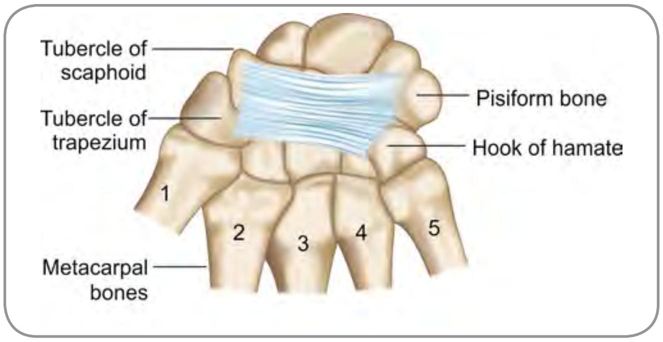


Fig. 17.10: Attachments of flexor retinaculum

The proximal border blends with the deep fascia of the forearm. The central part of the distal border is continuous with the apex of palmar aponeurosis. The anterior surface of the retinaculum gives attachment to the thenar and hypothenar muscles on the respective sides. The ulnar nerve and vessels run on the medial part of the anterior surface to reach the palm. However, a thin fibrous sheet stretches from the anterior surface to the lateral lip of pisiform over the ulnar nerve and vessels. Therefore, it appears that the ulnar nerve and vessels run through a small canal This fibrous sheet is often described as a superficial part or extension of the flexor retinaculum. The tendon of palmaris longus crosses the central part of the anterior surface to join the palmar aponeurosis; the tendon also blends with the flexor retinaculum. Palmar branches of the ulnar and median nerves also cross the anterior surface. The posterior (or deep) surface of the retinaculum is the anterior wall of the carpal tunnel and is related to the structures transmitted in the tunnel.

Structures under cover of flexor retinaculum: The flexor retinaculum is a restraining strap across the wrist. It converts the anterior concavity of the carpus (wrist) into a tunnel by bridging across it. Structures passing from the forearm to palm go through this tunnel. The tendons of flexor digitorum superficialis and flexor digitorum profundus along with their common synovial sheath, the tendon of flexor pollicis longus and its synovial sheath and the median nerve pass under cover of the retinaculum. Therefore, these are the contents of the carpal tunnel.

Functions of flexor retinaculum:

- It acts as a tie-beam to maintain the arch of the carpus; the anterior concavity of the carpus is enhanced by the retinaculum.
- It is a restraining band; in its action of bridging across the concavity of the carpus, it converts the carpal gutter into a carpal tunnel for the structures of the forearm to pass to the palm. However, the same structures may fall forward during flexion of the wrist or fingers if the retinaculum would not be restricting and keeping them in position.
- It gives attachment to the thenar and hypothenar muscles.

Added Information

- The flexor retinaculum maintains the arch formed by the carpal bones; the arch is dorsally convex and ventrally concave. The retinaculum acts as a tie-beam of the arch.
- The tie-beam is attached to the margins of the arch, i.e. the marginal carpal bones—pisifo m and hamate medially; scaphoid and trapezium laterally.
- The proximal part of the retinaculum extends between the pisiform and the tubercle of scaphoid; both these are rounded prominences. The distal part extends between the hook of hamate and the tubercle of trapezium; the anterior lip of the groove on trapezium is its tubercle too. Both the hook of hamate and the tubercle of trapezium can be considered as two crests—the crests which are the ossified portions of the distal part of the retinaculum.
- A thin fibrous band extends from the anterior surface of the flexor retinaculum to the lateral lip of pisiform bone over the ulnar nerve and vessels. This extension is usually referred to as the superficial part of the retinaculum. Therefore a canal is formed between the superficial part and the retinaculum proper, through which the ulnar nerve and vessels pass. This canal is the ***ulnar canal*** or the ***Guyon's canal***.

Clinical Correlation

Carpal tunnel syndrome

- Carpal tunnel is a passage between the carpal bones and the flexor retinaculum. Most of it is occupied by the flexor tendons and their synovial sheaths. The median nerve passes through the tunnel. Any increase in the volume of contents of the tunnel can compress the median nerve. This may occur because of inflammation in the synovial sheaths (usually the ulnar bursa). Pressure on the nerve gives rise to burning pain in the lateral three and a half-digits. Skin over the thenar eminence is spared because it is supplied by the palmar cutaneous branch of the median nerve that arises above the level of the flexor retinaculum and descends superficial to it. The carpal tunnel syndrome can be treated by incising the flexor retinaculum.
- The distal sk n crease on the anterior aspect of wrist (identified by its slight convexity towards the palm) indicates the proximal border of the flexor retinaculum. Behind the midpoint of this crease is the median nerve and still behind is the lunate bone. Forward dislocation of the lunate bone compresses the median nerve against the flexor retinaculum.

Palmar Aponeurosis

This is the condensation of deep fascia in the palm. It is triangular in shape, dense and strong, located in the middle of the palm and consist of longitudinal fibres.

- Its apex is directed proximally, attached to the distal border of flexor retinaculum and also receives the tendon of palmaris longus.
- The base, which is directed distally, divides into four slips, one for each finger (other than the thumb). These slips are attached by a thin band of transverse fibres on their deeper aspects. Beyond the transverse fibres, each slip divides into two; the divisions pass on either side of the finger and are attached by fibrous strands to the sides of the metacarpophalangeal joints, proximal phalanges and the deep transverse metacarpal ligament. In this way, an aperture is formed between the two slips, and the tendons of the flexor digitorum superficialis and profundus (for the digit) pass through this aperture. Between the divisions, the distal border of the slips loosely join the proximal borders of fibrous flexor sheaths.
- The medial and lateral borders of the aponeurosis are continuous with the thin fasciae (thenar and hypothenar fasciae) covering the thenar and hypothenar muscles respectively. In addition, a fibrous septum passes backwards from each border; the septum from the medial border, called the medial palmar septum, gets attached to the whole length of the anterior aspect of the fifth metacarpal bone; the septum from the lateral border, called the lateral palmar septum, gets attached to the whole length of the anterior aspect of the first metacarpal bone. These septa divide the palm into three compartments—***hypothenar compartment*** which is medial to the medial septum, ***thenar compartment*** which is lateral to the lateral septum and the ***intermediate (or central) compartment*** which is between the medial and the lateral septa.

Flexor tendons, lumbrical muscles and the superficial palmar arch lie under cover of the palmar aponeurosis. Digital arteries arising from the arch and digital branches of the median and ulnar nerves, pass distally under cover of the aponeurosis and enter the digits by passing under the free distal edge of the aponeurosis in the intervals between the digits. Thus two tunnel systems are seen—one for the passage of the flexor tendons and the other for the lumbricals and digital neurovasculature. The two systems alternate deep to the palmar aponeurosis.

Clinical Correlation

The fibres of the palmar aponeurosis may undergo progressive shortening. This results in deformities of the hand and restriction of finger movements. The fourth and fifth digits remain in a state of flexion at the metacarpophalangeal and proximal interphalangeal joints. Operative removal of restricting fibres can give relief. The condition is called ***Dupuytren's contracture.*** It is usually bilateral and is seen in men over 50 years of age; though a clear cut cause is unknown, genetic predisposition is noted.

Fibrous Flexor Sheaths

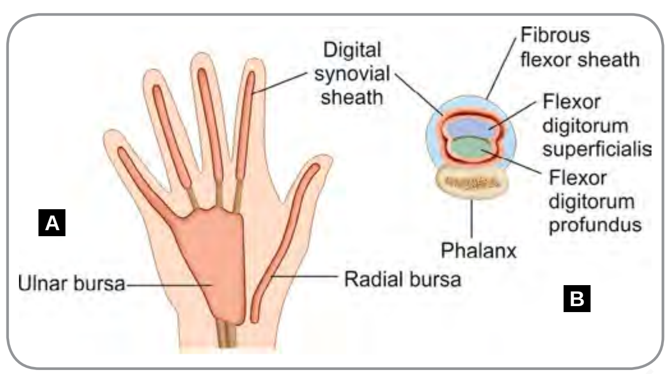
The fibrous flexor sheaths are condensations of deep fascia in the palmar aspects of the fingers. These sheaths extend from the heads of metacarpals to the bases of distal phalanges. The fibrous sheaths arch over from one side of the phalanges, metacarpophalangeal joints and interphalangeal joints to the other side. An osseofibrous tunnel is thus formed with the bones forming the dorsal wall of the tunnel and the fibrous sheath forming a curved wall on the medial, ventral and lateral aspects. The tunnel is closed distally by the attachment of the sheath itself to the distal phalanx beyond the insertion of the flexor digitorum profundus (and the insertion of flexor pollicis longus in the thumb).

The long flexor tendons to the concerned finger enter into the tunnels and run distally. The sheaths prevent the tendons from being pulled away during flexion (bowstringing).

Synovial sheaths of flexor tendons (Figs 17.11A and B): The long flexor tendons pass through osseofibrous tunnels formed by the flexor retinaculum and the fibrous flexor sheaths. They tend to rub against these structures and the bones which complete the tunnels. To avoid friction effects, the tendons are provided with lubricating synovial sheaths. One area of friction is the carpal tunnel; the other is the area of fibrous flexor sheaths. So the tendons have carpal synovial sheaths (or the proximal sheaths posterior to flexor retinaculum) and dig tal synovial sheaths (or the distal sheaths posterior to the fibrous flexor sheaths). The metacarpal of the thumb is short and this factor brings the carpal synovial sheath and the digital synovial sheath of the thumb close to each other and they merge together. The sheaths of the little finger may also join together. The sheaths of other fingers remain separate.

The carpal sheaths of the four superficialis tendons and the four profundus tendons are united to form the common synovial sheath, also called the ***ulnar bursa***. This is the largest of all synovial sheaths; it commences about 2.5 cm above the flexor retinaculum and passes into the palm. It extends till the middle of the palm. But the sheath related to the little finger

contd...



Figs 17.11A and B: A. Synovial sheaths of tendons on the front of the wrist and hand **B.** Transverse section across a digit showing the arrangement of the flexor tendons; Note the common synovial sheath for superficialis and profundus

contd ..

continues as the digital sheath of the little finger and ends at the base of the distal phalanx. The tendons invaginate the common sheath from the lateral aspect. The synovial sheath of the flexor pollicis longus (otherwise called the radial bursa) commences about 2 5 cm above the flexor retinaculum, continues into the palm and extends till the insertion of the tendon at the distal phalanx. The synovial sheaths of the middle three fingers commence around the middle of the palm, a little distal to the common synovial sheath. All of them end at the bases of the distal phalanges.

Clinical significance: As the digital sheath of the little finger communicates with the common sheath, infections of the sheath of little finger are dangerous and can spread to the common sheath. The carpal sheath of the thumb may sometimes communicate with the common synovial sheath. In such cases, infection from the digital sheath of the little finger can spread to the digital sheath of the thumb. Swelling of the ulnar bursa (which occurs when there is chronic inflammation leading to accumulation of inflammatory secretions) produces a swelling in the palm and another in the anterior forearm since the ulnar bursa commences above the flexor retinaculum. There is a constriction between the two swellings in the portion where the flexor retinaculum resists any increase in size. Therefore, an hour glass swelling is seen, above and below the flexor retinaculum. Pressure on one side of the hour glass forces the fluid to the other side behind the retinaculum causing a condition called ***compound palmar ganglion***.

Vincula: It is essential to understand the development of a synovial sheath to understand the occurrence of vincula. A tendon invaginates into a synovial bag; this leads to the formation of visceral and parietal layers of the synovial sheath with a narrow synovial cavity in between. The parietal layer comes to line the fibrous flexor sheath and the visceral layer covers the tendon. At the place where the two layers are continuous with each other, it appears that the tendon is suspended from the fibrous flexor sheath by a double fold of synovium. This double fold is the mesotendon. Blood vessels to the tendon pass through the mesotendon. In due course of time, due to compressed approximation of the two layers, most of the mesotendon breaks down and disappears Only where vessels run through, that portion of the mesotendon remains. Such remnant portions of the mesotendon are the vincula (singular vinculum). The terminal portions of the mesotendons of flexor digitorum superficialis, flexor digitorum profundus and flexor pollicis longus remain as triangular synovial folds called the vincula brevia (short vincula). In front of the proximal phalanges, thin bands of synovial folds are present. These are the vincula longa (long vincula). As already seen, the vincula convey blood vessels to the tendons.

The fibrous sheaths are attached to the palmar ligaments of the metacarpophalangeal joints. These attachments provide anchorage to the sheaths. Each fibrous flexor shea h crosses three joints—metacarpophalangeal joint, proximal interphalangeal joint and distal interphalangeal joint. The sheaths cannot be thick against the joints for mechanical reasons; they have to pliable here so as to permit flexion–extension of the joints. So they are thin and the fibres are arranged in a criss-cross fashion against the joints. Anterior to the bodies of the proximal and middle phalanges, the fibres are transversely arranged, curved and strong. The differences in the arrangement and texture of fibres give rise to the two parts of a fibrous flexor sheath—cruciate part where the fibres criss-cross; annular part where the fibres are transverse. When the fingers are flexed, the long flexor tendons glide over the cruciate and annular parts; therefore, these parts are sometimes referred to as pulleys; the tendons glide and pass over these parts just as ropes would glide and pass over the pulleys; thus there are thick and stiff annular pulleys and thin and lax cruciform pulleys.

Dissection

Open and stretch the hand of the cadaver. Make a longitudinal incision along the midline of the palm from the distal carpal crease to the base of the middle finger. Make two transverse incisions at the proximal and distal ends of the longitudinal incision. These two transverse incisions will be along the distal carpal crease and along the bases of the medial four fingers. Make a longitudinal incision along the palmar surface of the thumb and one of the other fingers. Slowly reflect the skin. The superficial fascia of the palm is thick, but the skin and fascia in the fingers are thin. So proceed slowly and steadily. If you encounter nerves and vessels, clean them carefully and try to preserve them. Identify and define the palmar aponeurosis. Identify and define the thenar and hypothenar fasciae and muscles. See the Palmaris brevis muscle over the hypothenar eminence. Using a blunt dissection, separate the palmar aponeurosis from the under ying structures. Keeping your fingers underneath the aponeurosis, cut it close to its apex and reflect it distally. The flexor retinaculum and the superficial palmar arch are exposed. Study them. Clean and define the various vessels and nerves. Define the limits,boundaries and contents of the carpal tunnel. Study the thenar and hypothenar muscles in detail. Hold the flexor digitorum profundus tendons in the distal forearm and transect them there. Study the deeper muscles and structures.

See and study the fibrous flexor sheaths in the thumb and the finger. Identify and study whatever digital nerves and vessels possible.

MUSCLES OF PALM (TABLE 17.2)

The muscles of the palm are placed in five (sets of) osseofibrous compartments. It is necessary to recollect the details of these compartments before studying the muscles proper.

As already noted, the medial and the lateral palmar septa along with the palmar aponeurosis, divide the palm into three basic compartments. These are the medial, central and lateral compartments.

1. ***Medial compartment:*** It is the hypothenar compart ment bounded laterally by the medial palmar septum and anteriorly by the hypothenar fascia; it contains the

hypothenar muscles—abductor digiti minimi, flexor digiti minimi brevis and opponens digiti minimi.

2. ***Central compartment:*** It is the compartment bounded on the medial and lateral sides by the medial and lateral palmar septa and anteriorly by the palmar aponeurosis; it contains the long flexor tendons and their synovial sheaths, the lumbrical muscles (which are the short muscles of the palm and are four in number), the superficial palmar arch and the digital vessels and nerves.
3. ***Lateral compartment:*** It is the thenar compartment bounded medially by the lateral palmar septum and anteriorly by the thenar fascia; it contains the thenar muscles—abductor pollicis brevis, flexor pollicis brevis and opponens pollicis.

A transverse sheet of fascia extends from the anterior aspect of the third metacarpal bone to the anterior aspect of the first metacarpal bone. The lateral palmar septum actually merges with the ventral aspect of this fascia (and so, the lateral septum is variedly described to be joining the first metacarpal or the third metacarpal; both are true and both are indirect). A deeper compartment, deep to the transverse fascia is thus earmarked and is the adductor compartment.

Adductor compartment: It is the deepest muscular compartment of the palm and is bounded anteriorly by the transverse sheet of fascia; it contains the adductor pollicis muscle.

Between the metacarpal bones, connective tissue in the surrounding area form small compartments for the interossei muscles.

Table 17.2: Muscles of palm

Muscle	Origin	Insertion	Action	Nerve supply
Muscles of the thenar compartment				
Abductor pollicis brevis	• Tubercle of scaphoid • Tubercle of trapezium • Adjoining part of flexor retinaculum	• Lateral side of base of proximal phalanx of thumb • Some fibres to dorsal digital expansion	• Abduction of thumb at metacarpophalangeal and carpometacarpal joints. • Abduction is associated with medial rotation	Median nerve (C8, T1)
Flexor pollicis brevis	***Superficial head:*** • Tubercle of trapezium (distal part) • Flexor retinaculum (adjoining part) ***Deep head:*** Trapezoid and capitate bones	Lateral side of base of proximal phalanx of thumb	Flexion of thumb	***Superficial head:*** Median nerve (C8, T1) ***Deep head:*** Deep branch of ulnar nerve (C8, T1)
Opponens pollicis	• Tubercle of trapezium • Flexor retinaculum (adjoining part)	Lateral half of palmar surface of first metacarpal bone	Opposition of thumb (flexion plus medial rotation)	• Median nerve (C8, T1) • Sometimes from deep branch of ulnar nerve also
Muscle of the adductor compartment				
Adductor pollicis	***Oblique head:*** • Capitate bone • Bases of 2nd and 3rd metacarpals ***Transverse head:*** Palmar aspect of 3rd metacarpal bone (distal two-thirds)	• Medial side of base of proximal phalanx of thumb • Some fibres into dorsal digital expansion	• Adducts the thumb from flexed or abducted position • The movement is forceful in gripping	Deep branch of ulnar nerve (C8,T1)
Muscles of the hypothenar compartment				
Abductor digiti minimi	• Pisiform bone • Tendon of flexor carpi ulnaris • Pisohamate ligament	Ulnar side of base of proximal phalanx of little finger	Abducts little finger at metacarpophalangeal joint	Deep branch of ulnar nerve (C8, T1)
Flexor digiti minimi	• Hook of hamate (proximal part) • Adjoining part of flexor retinaculum	Ulnar side of base of proximal phalanx of little finger	Flexion of little finger at metacarpophalangeal joint	Deep branch of ulnar nerve (C8, T1)
Opponens digiti minimi	• Hook of hamate (distal part) • Adjoining part of flexor retinaculum	Medial surface of 5th metacarpal bone	Flexes the fifth metacarpal bone and rotates it laterally (makes palm hollow)	Deep branch of ulnar nerve (C8, T1)

Interosseous compartments: These are the tiny osseofibrous compartments between the metacarpal bones; they are occupied by the interosseous muscles.

Palmaris Brevis

This is a small, thin muscle present in the subcutaneous tissue over the hypothenar eminence. Since it is in the subcutaneous tissue and thus anterior to the hypothenar fascia, it is not in the hypothenar compartment. Laterally, it is attached to the flexor retinaculum and the palmar aponeurosis. Medially, it is attached to the skin along the ulnar border of the hand. Supplied by the superficial branch of the ulnar nerve, the muscle causes wrinkling of the skin over the medial side of the palm and thus helps in providing a better grip. It also helps in 'cupping' the palm. It protects the ulnar nerve and artery.

> ***Panniculosus carnosus:*** Also called panniculosus musculosus. This is a layer of striated muscles present in the subcutaneous tissue (Latin.panniculus=cloth, covering; Latin.carneus=flesh). It is a layer of continuous muscular sheet in lower animals; a grazing animal ***twitches its withers***; the subcutaneous muscle is twitched toward off insects and birds. In humans, this is not a continuous layer; it is present in three areas—Palmaris brevis (in the palm), platysma (in the face and neck) and dartos (in the sc otum) are the three classic examples. Some muscles of facial expression are also examples of panniculosus carnosus. In other areas, this layer of muscle is usually absent. However, it may be represented by thin isolated strands of muscle tissue here and there.

Additional Notes on the Thenar Muscles (Fig. 17.12)

- The three muscles of the thenar compartment form the thenar eminence of the palm.
- The most superficial and anterolateral of them is the abductor pollicis brevis (short abductor of the thumb). Apart from abduction, it helps the opponens pollicis by rotating the proximal phalanx in early opposition.
- Arising by two heads, the two bellies of flexor pollicis brevis (short flexor of the thumb) flank the tendon of abductor pollicis brevis. The bellies merge into a single tendon which may contain a sesamoid bone. The innervation of the two bellies is usually different; la ger superficial belly is supplied by the recurrent branch of the median nerve and the smaller deep belly is supplied by the deep palmar branch of the ulnar nerve.
- The medial rotation effected by opponens pollicis is helpful even when there is no complete opposition; it is required for picking up objects
- The flexor pollicis brevis and opponens pollicis are in the same plane and usually appear to be a single sheet of muscle. This sheet resembles the pronator teres muscle of the forearm, both in the direction of fibres and action. Hence, the sheet is sometimes referred to as the 'pronator pollicis'. It should also be remembered that opposition is always accompanied by flexion and the two muscles act in unison. It is also a fact that 'useful' opposition is possible only with accompanying flexion.

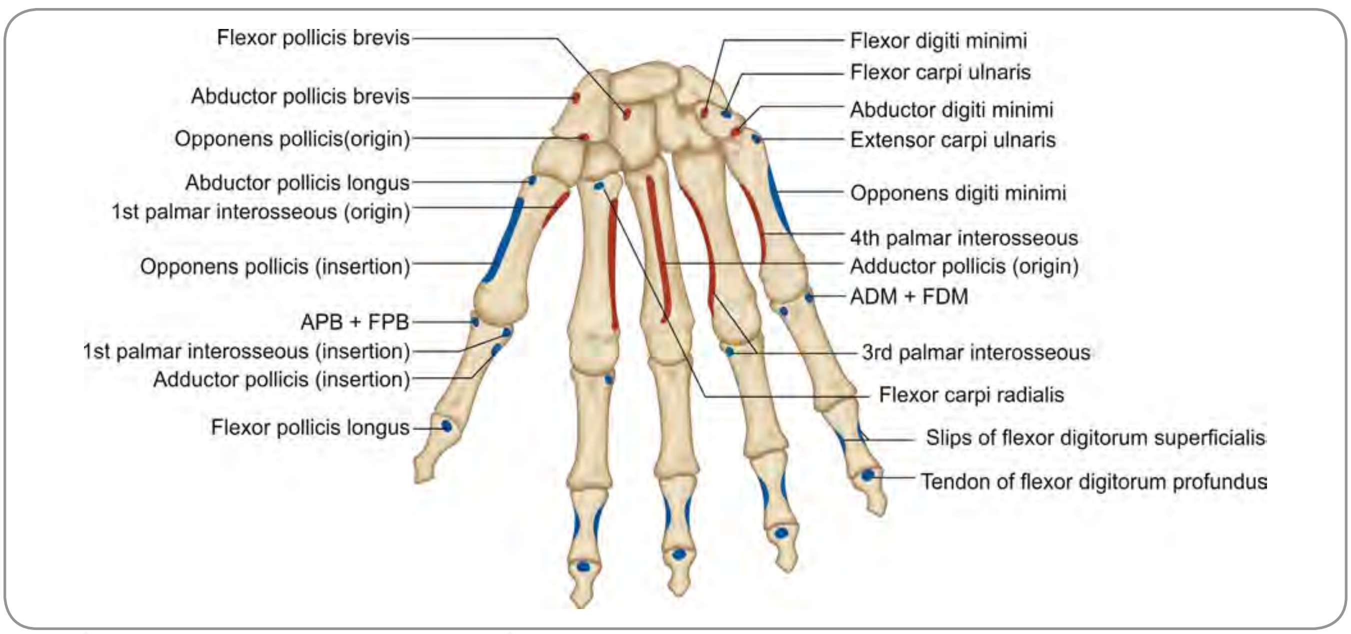


Fig. 17.12: Thenar and hypothenar muscles-origin and insertion (APB: Abductor pollicis brevis; FPB: Flexor pollicis brevis; ADM: Abductor digiti minimi; FDM: Flexor digiti minimi)

Additional Notes on the Adductor Pollicis (Fig. 17.13)

- This muscle has two heads of origin which are separated by the radial artery.
- Its tendon of insertion usually has a sesamoid bone.

Additional Notes on Movements of the Thumb

Movements of the thumb are extremely important for most of the civilised functions of mankind. Acivities of the hand which require precision and detailing depend on the position and movements of the thumb. Wide range of freedom of these movements is due to the first metacarpal being independent. The bone also enjoys the benefit of a mobile joint at both its ends; the carpometacarpal and the metacarpophalangeal joints of the thumb are capable of movements.

Several muscles are responsible for producing movements of the thumb.

- ***Flexion:*** Flexor pollicis longus and flexor pollicis brevis;
- ***Extension:*** Extensor pollicis longus and extensor pollicis brevis assisted by abductor pollicis longus;
- ***Adduction:*** Adductor pollicis assisted by the first dorsal interosseous muscle;
- ***Abduction:*** Abductor pollicis longus and abductor pollicis brevis;
- ***Opposition:*** Opponens pollicis; however, 'real' movement of opposition requires the activity of various muscles.

Opposition is a complex movement. It can be defined as the movement that brings the pad of the thumb to the pad of any other finger (and also holding it there). Pinching, holding a cup by its handle, counting numbers on the fingers and writing are some examples where opposition is essential and can be demonstrated clearly. If we imagine opposition of the thumb from an extended position, initial movements to occur are abduction and medial rotation; these two movements are brought about by opponens pollicis by acting on the carpometacarpal joint Cupping of the palm occurs. Further opposition is brought about by flexion at the metacarpophalangeal joint which is executed by the action of flexor pollicis muscles. It is reinforced and made more powerful by the actions of adductor pollicis and flexor pollicis longus; these two muscles adduct the thumb; due to this, the already opposed thumb can exert more force on the fingertip with which it is in contact. Thus, more muscles contribute to opposition.

The opposing finger also moves. It has to be adequately flexed; this is brought about by the (concerned) profundus tendon, superficialis tendon, lumbrical and interossei. In pulp-to-pulp opposition, movements of the thumb and those of the opposing finger are equally important.

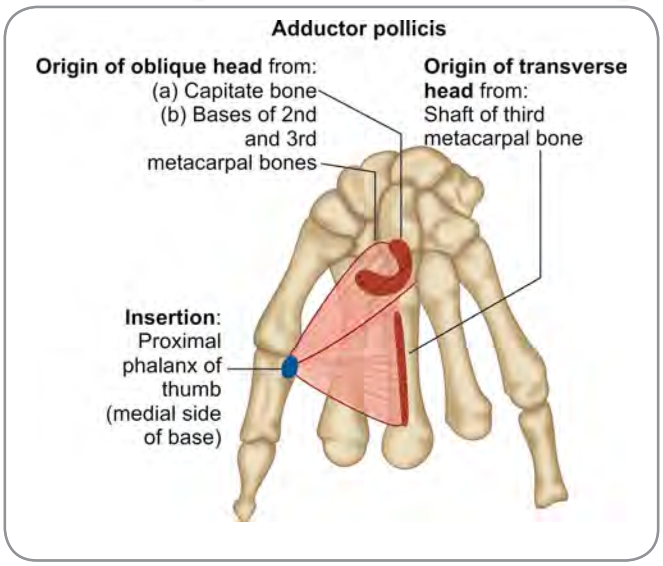


Fig. 17.13: Attachment of adductor pollicis

Additional Notes on the Hypothenar Muscles

- The three muscles of the hypothenar compartment form the hypothenar eminence of the palm.
- The most superficial of the three is the abductor digiti minimi; this muscle (unlike its thenar counterpart) acts on the metacarpophalangeal joint and not on the carpometacarpal joint (Fig. 17.12).
- The flexor digiti minimi may very often be absent.
- Though opponens digiti minimi is a separate muscle and acts exclusively on the carpometacarpal joint, the amount of rotation produced at the latter joint is very minimal. So the little finger cannot be drawn opposite the other fingers; it can be flexed and minimally rotated to oppose the thumb, where the contribution of thumb is larger.
- Flexion and rotation of the little finger help in increasing the concavity of the palm.

Additional Notes on the Lumbricals (Table. 17.3)

- These are four slender muscles and have been named after their resemblance to a worm (Latin. Lumbricus=earthworm).
- The position of a finger brought about by the action of a lumbrical muscle (Fig. 17.14) (flexion at the metacarpophalangeal joint and extension at the interphalangeal joint) is called the ***writing position***. It is also referred to as the ***Z movement***.

The lumbricals pass on the lateral aspects of the metacarpophalangeal (MP) joints and attach to the dorsal expansions. By virtue of this, they causes flexion at MP joints and extension at interphalangeal (IP) joints.

- ***Pull on MP joint:*** From ventral to dorsal—So, flexion
- ***Pull on IP joint:*** From dorsal to dorsal—So, extension

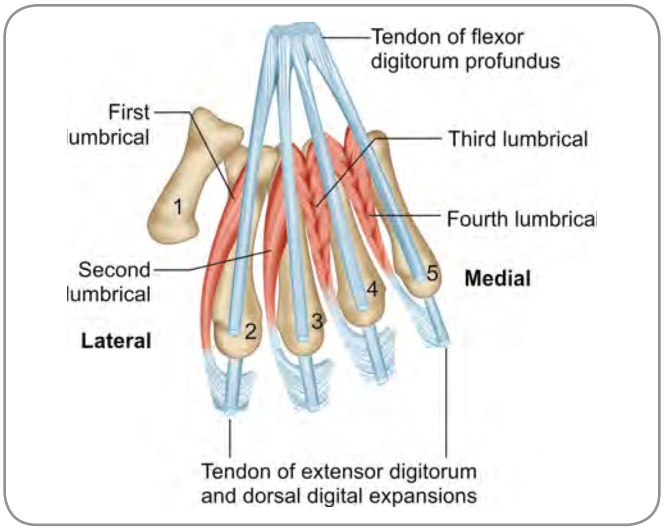


Fig. 17.14: Diagram to show attachments of lumbrical muscles

Clinical Correlation

- ***Testing of abductor pollicis brevis:*** The thumb is abducted against resistance; the muscle can be felt if it is normal. It will be the first muscle to show weakness in cases of carpal tunnel syndrome.
- ***Testing of flexor pollicis brevis:*** The thumb is flexed against resistance; the muscle can be felt if it is normal. However, action of flexor pollicis longus should also be accounted for.
- ***Testing of opponens pollicis:*** The patient is asked to touch the tip of the little finger with the tip of the thumb or to make a circle with the thumb and the index finger.
- ***Testing of adductor pollicis:*** The patient is asked to keep both palms together A piece of thick paper or card is kept between the thumbs and the index fingers of the patient The patient is asked to grip the paper or card tightly. The thumbs are adducted to grip tight. If the adductor pollicis

contd...

Table 17.3: Lumbricals— These are four small muscles that take origin from the tendons of the flexor digitorum profundus.

Origin	• First lumbrical from radial side of tendon for index finger • Second lumbrical from radial side of tendon for middle finger • Third lumbrical from contiguous sides of tendons for middle and ring fingers • Fourth lumbrical from contiguous sides of tendons for ring and little fingers
Insertion	Each muscle ends in a tendon that passes backwards on the radial side of one metacarpophalangeal joint and is inserted into the lateral basal angle of the extensor expansion for that digit in the following order: • Tendon of first lumbrical into second digit • Tendon of second lumbrical into third digit • Tendon of third lumbrical into fourth digit • Tendon of fourth lumbrical into fifth digit
Nerve supply	• First and second lumbricals from median nerve (C8, T1) • Third and fourth lumbricals from ulnar nerve deep branch (C8,T1)
Action	• Flexion of metacarpophalangeal joint, and • Extension of interphalangeal joint of digit concerned
Notes	Help in fine movements of fingers, as in writing or threading a needle

Table 17.4: Comparison of palmar and dorsal interossei

	Palmar interossei	**Dorsal interossei**
Features common to both	• Four palmar interossei • Numbered from lateral to medial side • Insertion of each muscle into dorsal digital expansion of one digit • Movements described with reference to the third digit • Nerve supply from deep branch of ulnar nerve (C8, T1) • They flex the metacarpophalangeal joint and extend the interphalangeal joints of the digit concerned	• Four dorsal interossei • Numbered from lateral to medial side • Insertion of each muscle into dorsal digital expansion of one digit • Movements described with reference to the third digit • Nerve supply from deep branch of ulnar nerve (C8, T1) • They flex the metacarpophalangeal joint and extend the interphalangeal joints of the digit concerned
	Palmar interossei	**Dorsal interossei**
Features different in the two	• Each muscle arises from one metacarpal • The third digit does not give origin to, or receive the insertion of any palmar interosseus muscle • These are adductors of the digit towards the line of the middle finger (Fig. 17.38B) • A palmar interosseus muscle may or may not be inserted into the base of the proximal phalanx • Palmar interossei take origin from, and are inserted into the first, second, fourth, and fifth digits (not the third)	• Each muscle arises from two adjoining metacarpals • The third digit gives origin to and receives insertions of two muscles (one on each side, medial and lateral) • These are abductors of digits away from the line of the middle finger (Fig. 17.38A) • A dorsal interosseus muscle is always inserted into the base of the proximal phalanx of the digit concerned • Dorsal interossei take origin from all five metacarpals and are inserted into the second, third and fourth digits (not first and fifth)

Clinical Correlation *contd...*

is affected, the flexor pollicis longus comes into play to grip tight and the interphalangeal joint is flexed. This test is called the ***Froment's test***; flexion of the distal phalanx while attempting to hold a paper or card between the thumbs and index fingers is called Froment's sign (named after Jules Froment, a 19th century physician). Froment's test becomes positive in ulnar nerve palsy.

- ***Testing of lumbricals:*** The patient is asked to hold his/her hand in such a way that the palm faces superiorly With resistance applied on the palmar surface of each proximal phalanx of digits 2 to 5 (index to little fingers), the patient is asked to flex the metacarpophalangeal joint of that particular digit. Resistance may also be additionally applied on the dorsal aspect of the middle and distal phalanges to test the extension of the interphalangeal joints.
- ***Testing of dorsal interossei:*** The patients's extended and adducted fingers are held between the examiner's thumb and index finger. The patient is asked to abduct against resistance offered by the examiner.
- ***Testing of palmar interossei:*** A sheet of paper is placed between the fingers of the patient. The patient is asked to 'hold the paper' between the fingers when the paper is being pulled by the examiner. If the paper is pulled away, it indicates that the patient is not able to hold the fingers together (deficiency of adduction (Table 17.4)).

POSTERIOR COMPARTMENT OF FOREARM AND DORSUM OF HAND

The posterior compartment of forearm lies behind the radius, ulna and the interosseous membrane. It is served by the radial nerve. Many muscles of this compartment take origin from the lateral epicondyle and the lateral supracondylar ridge of the humerus and so the compartment is posterolateral in the proximal part of the forearm and truly 'posterior' in the distal forearm only. The tendons of these muscles continue into the dorsum and the dorsal aspects of the fingers.

Though, there is functional continuity and harmony between the muscles of the posterior forearm and the dorsum, they are described separately for the sake of convenience.

MUSCLES OF THE POSTERIOR COMPARTMENT OF FOREARM

The muscles of the posterior compartment of forearm (back of forearm or posterior antebrachial) are the extensor–supinators and are present in two layers—superficial and deep.

The superficial muscles of the posterior compartment of forearm are (Table 17.5):

- Brachioradialis
- Extensor carpi radialis longus
- Extensor carpi radialis brevis
- Extensor digitorum
- Extensor digiti minimi
- Extensor carpi ulnaris
- Anconeus.

Additional Notes on Brachioradialis

Brachioradialis lies in the anterolateral aspect of the forearm and its upper fleshy part forms the lateral boundary of the cubital fossa. Here the radial nerve is deep to it (between it and the brachialis) (Fig. 17.15).

Near its insertion, its tendon is crossed by the tendons of abductor pollicis longus and extensor pollicis brevis. At the wrist, the radial artery is medial to the tendon (between it and the tendon of the flexor carpi radialis). The brachioradialis is an exceptional muscle of the extensor group, because it has rotated to the anterior aspect of humerus and thereby flexes the elbow; it is a developmental extensor but a functional flexor. It plays an important role during rapid movements and n flexion against resistance.

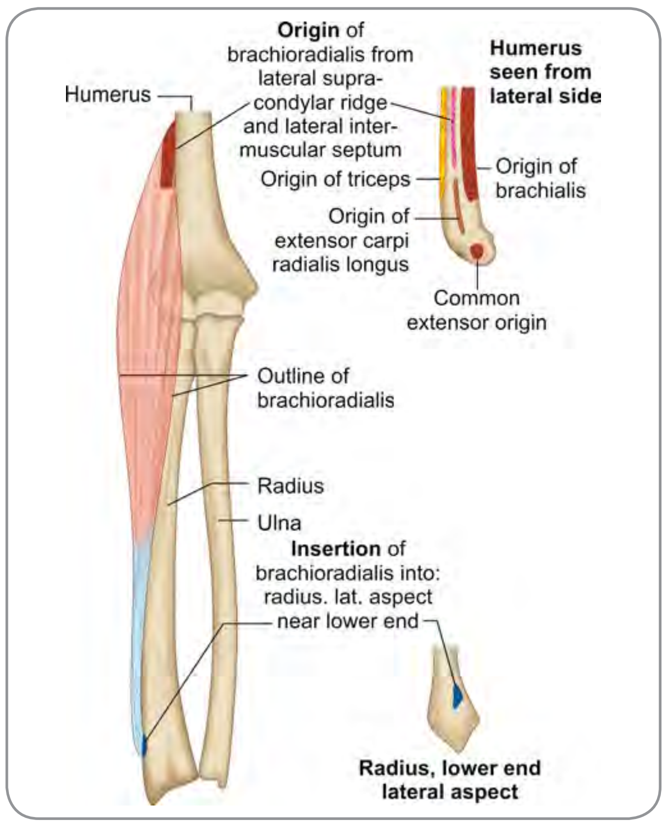


Fig. 17.15: Attachments of brachioradialis

Table 17.5: Superficial muscles of the posterior compartment of forearm

Muscle	Origin	Insertion	Act on	Nerve Supply
Brachioradialis	• Upper two-thirds of lateral supracondylar ridge of humerus • Lateral intermuscular septum	Lateral side of radius just above styloid process	• Flexes the forearm (especially in mid-prone position) • Supinates fully pronated arm and pronates fully supinated forearm (to midprone position)	Radial nerve (C5 C6, C7)
Extensor carpi radialis longus	• Lower one-third of lateral supracondylar ridge of humerus • Some fibres from lateral epicondyle • Some fibres from lateral intermuscular septum	Lateral s de of base of second metacarpal bone (dorsal aspect)	Actions common to both muscles: • Extension of wrist (along w th extensor carpi ulnaris) • Abduction of wrist (along with flexor carpi ulnaris) • They fix the wrist and assist powerful movements of hand	Radial nerve (C6, C7)
Extensor carpi radialis brevis	• Lateral epicondyle of humerus • Radial collateral ligament of elbow joint	Dorsal aspect of base of second and third metacarpal bones	Same as for extensor carpi radialis longus	Deep branch of radial nerve (C7, C8)
Extensor digitorum Old name applied clinically: Extensor communise	• Lateral epicondyle of humerus • The tendon splits into four parts one for each digit other than the thumb. Over the proximal phalanx the tendon for each digit divides into three slips—one intermediate and two collateral	• Intermediate slip for each digit into base of middle phalanx (dorsal aspect) • Collateral slips reunite and are inserted into the base of the distal phalanx (dorsal aspect)	Extension at: • Interphalangeal joints • Metacarpophalangeal joints • Wrist joint	Deep branch of radial nerve (C7, C8)
Extensor digiti minimi (Extensor digiti V)	Lateral epicondyle of humerus (The tendon is joined by the tendon of the extensor digitorum for fifth digit)	The tendon ends in the dorsal digital expansion (Fig 17.18) of the little finger through which it is inserted into: • Dorsal aspect of the base of middle phalanx • Base of distal phalanx	Extension of little finger at: • Metacarpophalangeal joint • Interphalangeal joints	Deep branch of radial nerve (C7, C8)
Extensor carpi ulnaris	• Lateral epicondyle of humerus • Posterior border of ulna (by an aponeurosis common to it, the flexor carpi ulnaris and flexor digitorum profundus)	Medial side of the base of fifth metacarpal bone	• Extension of wrist (along with extensor carpi radialis longus and brevis) • Adduction of hand (with flexor carpi ulnaris) • F xes the wrist during forceful movements of the hand (along with other muscles around the wrist)	Deep branch of radial nerve (C7, C8)
Anconeus	Lateral epicondyle of humerus (posterior aspect)	• Lateral aspect of olecranon process of ulna • Upper one-fourth of posterior surface of ulna	• Weak extensor of elbow • Moves ulna laterally during pronation	Branch from radial nerve (C7, C8, T1) given off in the arm and passing through medial head of triceps

Additional Notes on Extensor Carpi Radialis Longus and Extensor Carpi Radialis Brevis

The extensor carpi radialis longus is superficial to the brevis and is overlapped by the brachioradialis (Figs 17.16 and 17.17).

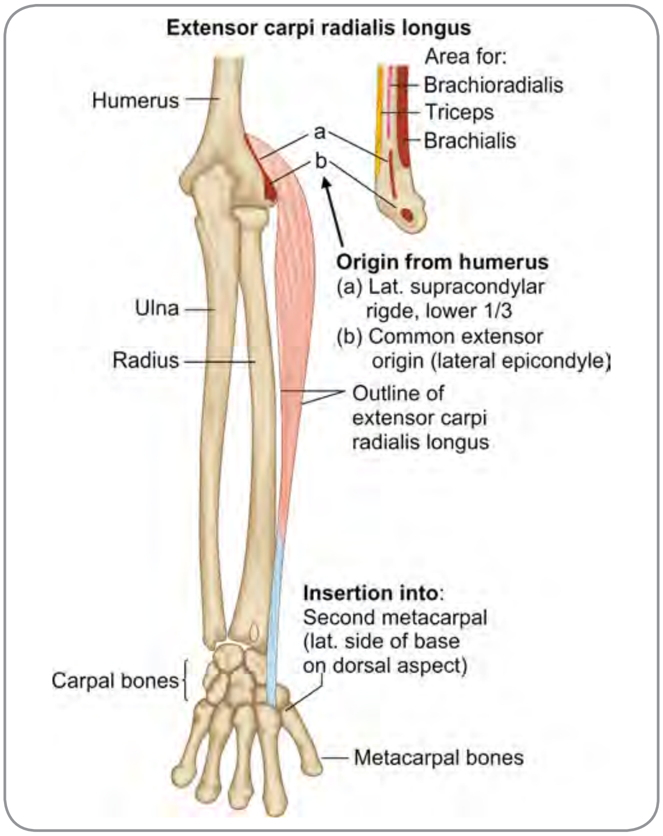


Fig. 17.16: Attachments of extensor carpi radialis longus

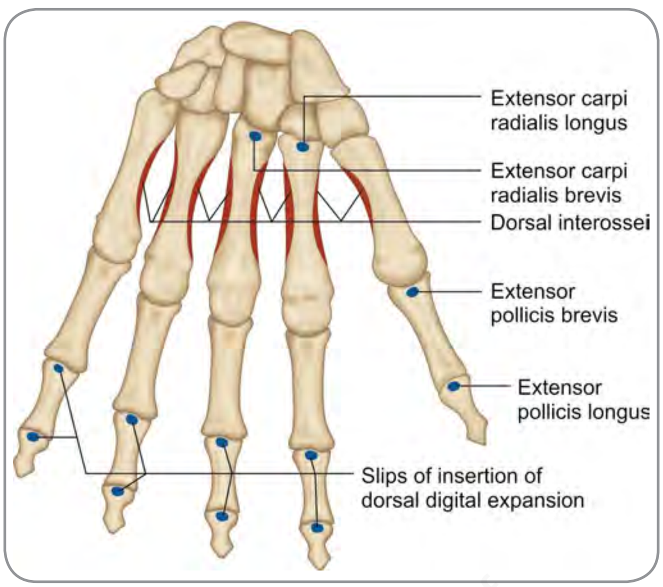


Fig. 17.18: Scheme to show muscular attachments

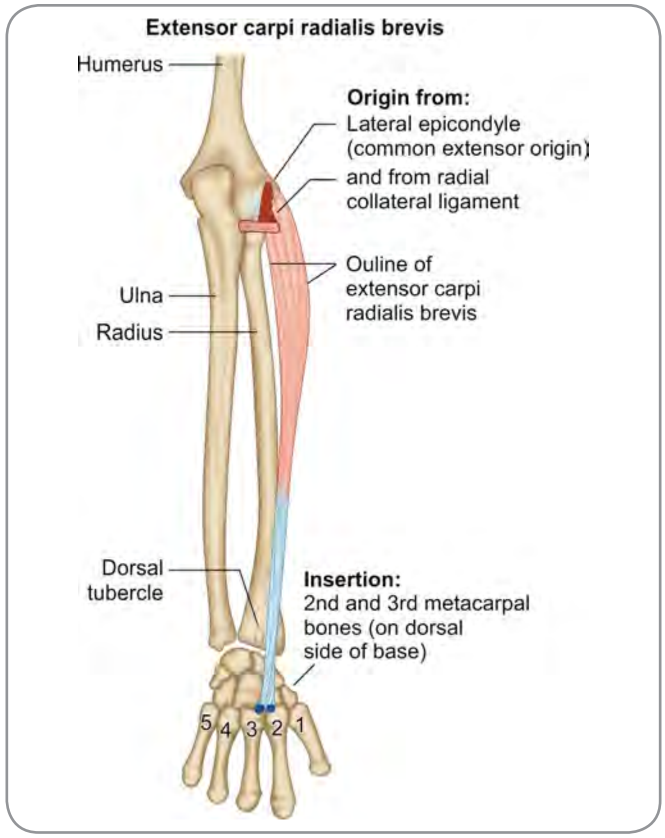


Fig. 17.17: Attachments of extensor carpi radialis brevis

The extensor carpi radialis brevis arises more distally; though much shorter than the longus muscle, it gets inserted adjacent to the insertion of longus due to its distal origin. The tendons of both the muscles come together by around the middle of the forearm and run distally; in the distal forearm they are crossed by the abductor pollicis longus and the extensor pollicis brevis muscles. At the lower end of the radius the tendons occupy a groove just behind the styloid process (and lateral to the dorsal tubercle). The longus tendon lies lateral to the brevis tendon. Here the two tendons pass deep to the extensor retinaculum. They are surrounded by a common synovial sheath. A little above their insertion, the tendons are crossed by the tendon of the extensor pollicis longus. The two muscles act in unison but the contribution of each muscle varies according to the situation. When the two of them act, they produce extension of wrist associated with abduction. When they act along with the extensor carpi ulnaris, they extend the wrist; in this situation, the brevis muscle works more. When acting with flexor carpi radialis, they produce abduction. While clenching a fist, both muscles act but the longus acts more; tight flexion of the medial four fingers is possible only when the two extensors produce adequate extension.

Additional Notes on Extensor Digitorum (Fig. 17.19)

It is otherwise called the extensor digitorum communis. The muscle belly gives rise to four tendons to the medial four digits. Along with the tendon of extensor indicis, they pass under cover of the extensor retinaculum, surrounded by a common synovial sheath. Distally the sheath extends for some distance beyond the retinaculum. Once on the dorsum, the tendons spread out to go to their respective digits. Proximal to the carpometacarpal joints, the tendons are interconnected by three fibrous strands (intertendinous fibrous connections); these connections keep the tendons together thus restricting individual flexion of the medial four digits. This is the reason why any of these fingers cannot be fully flexed when the others are fully extended. Extension of the digits is accompanied by fanning out of the digits (i.e. abduction of the second, fourth and fifth digits). This is an indirect action of the extensor digitorum.

Dorsal Digital Expansion and Insertion of the Extensor Digitorum (Fig. 17.20)

Over the proximal phalanx, the tendon (of that digit) inserts into a triangular membrane called the ***dorsal digital expansion*** (or the extensor expansion or the extensor hood) (Figs 17.21A and B). Each expansion is an aponeurosis present on the dorsal aspect of the proximal phalanx, the metacarpophalangeal joint and the head of the metacarpal. The expansion is triangular. It has an apex directed distally, and a broad base that lies dorsal to the metacarpophalangeal joint. It is anchored on the sides to the palmar ligaments. The extensor tendon, within the substance of the expansion, divides into three slips—a median slip and two lateral slips. The median or the central slip inserts into the base of the middle phalanx. The lateral slips (preferably called the collateral slips), emerging more from the sides of the triangle, pass distally, unite over the middle phalanx and insert into the base of the distal phalanx. The tendons of lumbricals and interossei join with the collateral slips.

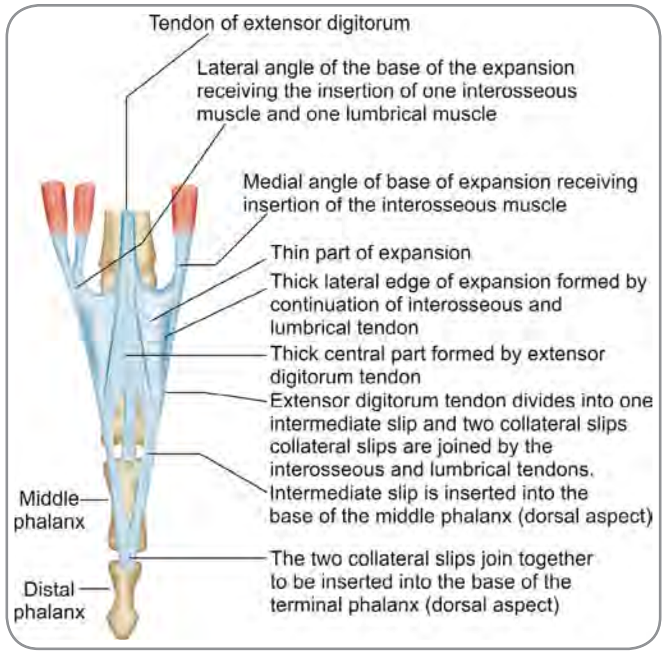


Fig. 17.20: Dorsal digital expansion and insertion of extensor digitorum

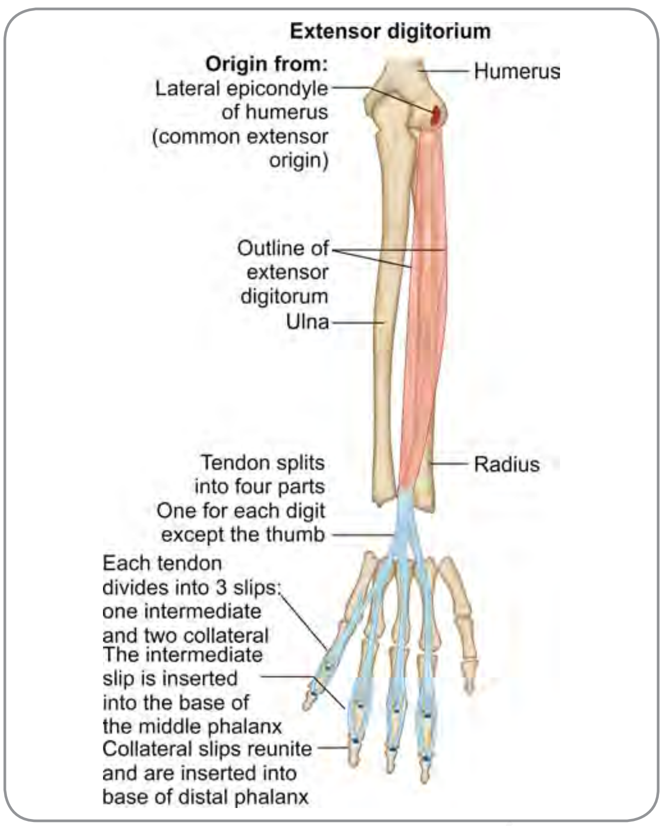
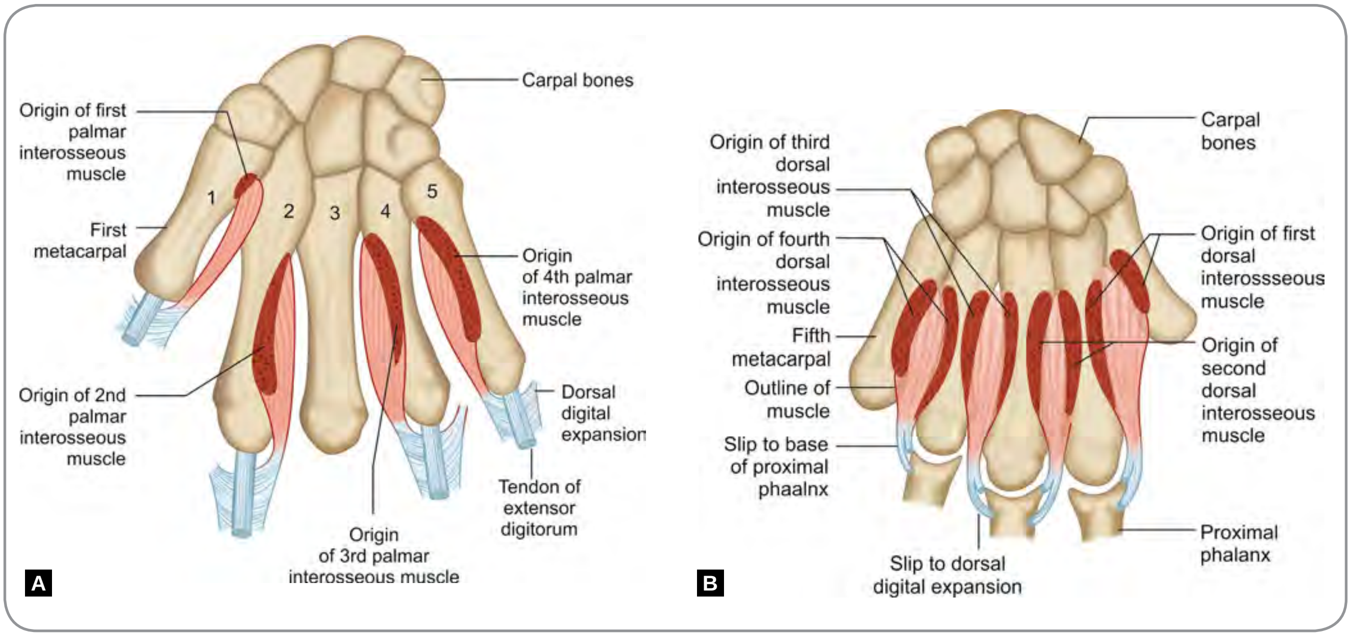


Fig. 17.19: Attachments of extensor digitorum

Additional Notes on Extensor Digiti Minimi (Fig. 17.22)

The extensor digiti minimi is often considered a detached part of the extensor digitorum. Its tendon runs through a separate compartment of the extensor compartment, enclosed within its own synovial sheath. The tendon then divides into two slips; the lateral of these slips joins with the tendon of the extensor digitorum to the little finger; however, all the three slips (two of extensor digiti minimi and one of the extensor digitorum) insert into the dorsal digital expansion of the little finger.



Figs 17.21A and B: A. Palmar interossei **B.** Dorsal interossei

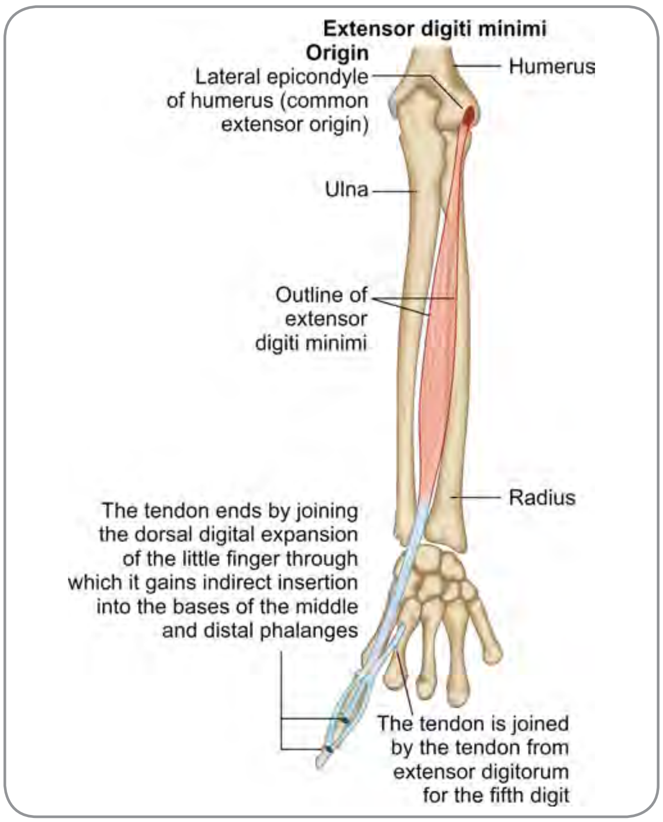


Fig. 17.22: Attachments of extensor digiti minimi

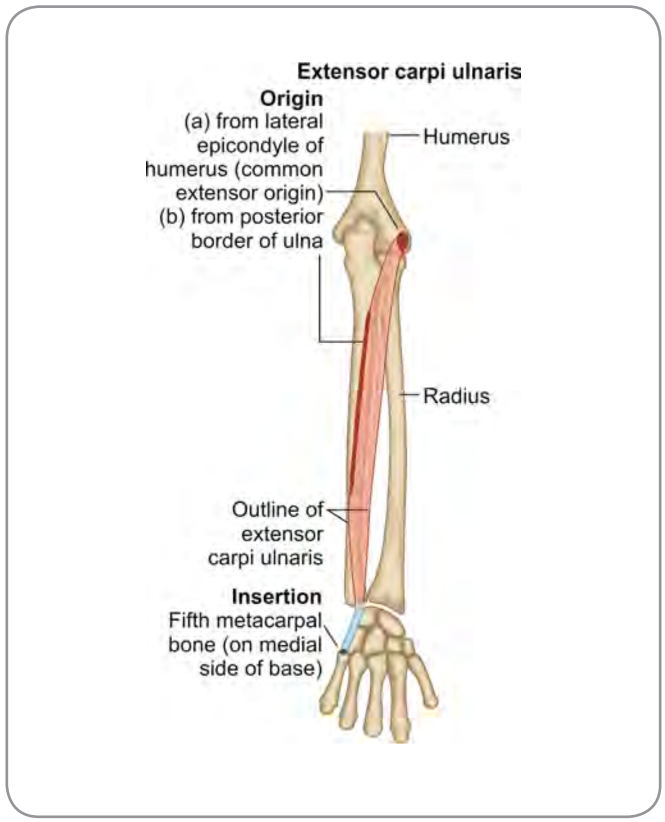


Fig. 17.23: Attachments of extensor carpi ulnaris

Additional Notes on Extensor Carpi Ulnaris (Fig. 17.23)

The muscle gives rise to a tendon that runs through a separate compartment of the extensor expansion within its own synovial sheath Acting with the extensor carpi radialis longus and brevis muscles, the extensor carpi ulnaris extends the wrist; acting with the flexor carpi ulnaris, it adducts the wrist.

Extensor apparatus: Other names—extensor expansion, extensor assembly, extensor mechanism, dorsal aponeurosis, aponeurotic sleeve. Each dorsal digital expansion is a triangular expansion of the tendon of the extensor digitorum muscle to that digit. However, fibrous connective tissue of the adjoining area adds up the expansion. A triangular aponeurotic sheet is thus formed on the dorsal aspect of the metacarpal head, metacarpophalangeal joint and the proximal phalanx. The basal portion of the expansion has transversely running fibres which closely hug around the metacarpal head and the metacarpophalangeal joint; these are connected to the palmar ligaments by sagittal fibrous bands on both sides. These attachments anchor the expansion and keep the extensor tendon in the midline of the digit aiding in effective action. The basal portion is the 'hood' of the expansion. Fibroareolar bands on either side connect the hood to the base of the proximal phalanx also. Immediately distal to the hood portion, the expansion has transverse and oblique fibres. These are the first set of contribution from the interossei and lumbrical tendons. Once the expansion splits into the median and collateral slips over the distal part of the proximal phalanx, most of the fibres of the extensor tendon pass through the median slip. The collateral slips receive the interosseous tendons. On the radial side, a little distal to the joining of the interosseous tendon, the lumbrical tendon joins. The collateral slips, thus become conjoined tendons. Transverse fibres of the expansion connect these tendons. The fibres of interossei and lumbricals run through the collateral slips, though a few of them go to the median slip. The two collateral slips unite over the middle phalanx to insert into the base of the distal phalanx. A triangular ligament connects the two collateral slips proximal to their union.

The union of various muscles in the dorsal digital expansion results in the extensor apparatus and its actions. The extensor tendons extend the metacarpophalangeal joints. Even if the extensor expansion is cut on the dorsal aspect of the proximal phalanx, traction on the corresponding tendon still causes extension; this is because of the pull of the fibro areolar bands on the proximal phalanx. Contraction of the extensor digitorum alone produces extension of the metacarpophalangeal and all interphalangeal joints. Since the interossei and lumbricals cross the metacarpophalangeal joints from the anterior to the posterior aspect, their contraction will cause flexion of the metacarpophalangeal joints; however since they are attached to the dorsal expansion and thus attached to the bases of the distal phalanges, the lumbricals produce extension of the interphalangeal joints and the interossei produce extension of interphalangeal joints and abduction–adduction of the fingers. The latter actions are well performed when the metacarpophalangeal joints are extended by the long extensors. So, simultaneous contraction of the extensor digitorum and lumbricals (and interossei also) produces metacarpophalangeal flexion and interphalangeal extension.

Special features of the extensor apparatus:

- The extensor apparatus is made up of fibrous and aponeurotic tissue and has no source of active force; but many of the intrinsic and extrinsic muscles of the hand join the apparatus. Thus active force is transmitted to the apparatus from muscular contraction.

contd...

contd...

- The extrinsic part of the apparatus is formed by the long extensor tendons and the intrinsic part by the interossei and lumbricals.
- The extensor apparatus develops passive tension on elongation; any movement of the hand that increases the length of the apparatus increases passive tension and activates the extensor mechanism
- The extrinsic extensor fibres pass dorsal to the metacarpophalangeal and interphalangeal joints; so contraction of the extensors produces extension of these joints.
- The oblique retinacular ligament connects the sides of the proximal phalanx and adjacent fibrous flexor sheath to the distal part of the dorsal expansion. This ligament runs distally from the palmar aspect in the region of the proximal phalanx; it is palmar to the proximal interphalangeal joint and dorsal to the distal interphalangeal joint. Elongation of the retinacular ligament increases tension in it. If flexion of the distal interphalangeal joint is attempted with the proximal joint in extension, the retinacular ligament elongates; increase in tension causes flexion of the proximal joint also. The retinacular ligament thus helps in coordination of the movements and position of the interphalangeal joints.
- Power of extension of interphalangeal joints decreases if the metacarpophalangeal joint is flexed.

Dissection

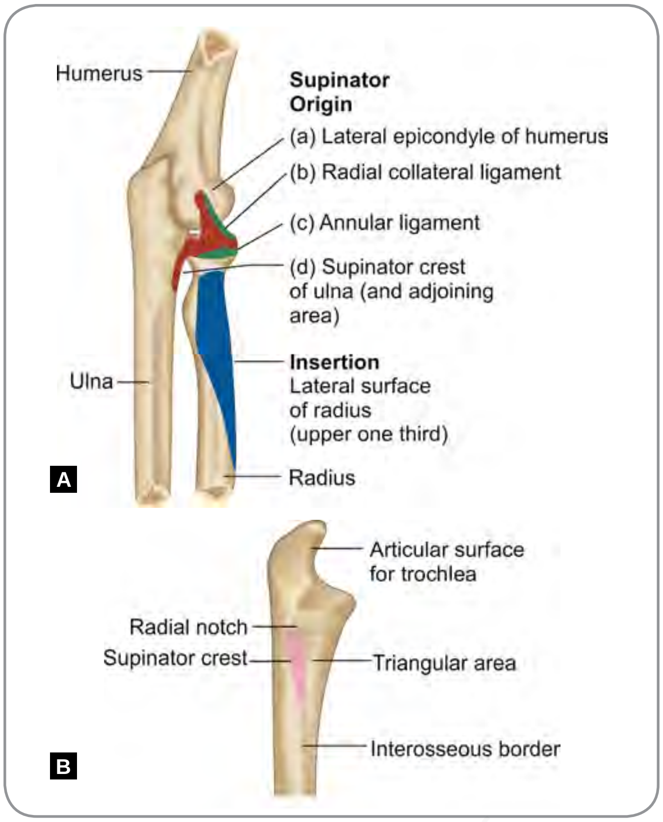
With the cadaver in the supine position, pronate the forearm and tie it up in that position. If necessary, turn the cadaver to the prone position and fix the forearm. Make a longitudinal incision along the midline of the forearm on the dorsal aspect from the olecranon to the wrist; make two transverse incisions at the proximal and distal ends of the longitudinal incision. Extend the longitudinal incision into the dorsum of the hand along the midline. Extend the same incision into the middle finger. With appropriate transverse incisions, reflect the skin flaps medially and laterally. Identify the extensor retinaculum. See the compartments of the retinaculum and study the various muscles and their tendons which run through these compartments. Try and trace one of the tendons into the dorsal digital expansion. After studying the muscles and their tendons transect one or two of them to see the deeper structures. See the outcropping muscles, anatomical snuff box and the various vessels and nerves. Study each one of them in detail.

The deep muscles of the posterior compartment of the forearm are (Table 17.6):

- Supinator
- Extensor pollicis longus
- Abductor pollicis longus
- Extensor indicis
- Extensor pollicis brevis

Additional Notes on Supinator (Figs 17.24A and B)

Starting from their origin, the fibres of the supinator wind around the posterior, lateral and anterior aspects of the



Figs 17.24A and B: A. Attachments of supinator muscle **B.** Lateral aspect of upper end of ulna showing the area of origin of the supinator

radius (in that order) to reach their insertion. The fibres thus have a spiral course that enables them to rotate the radius with ease. The muscle has two layers—superficial and deep. The deep branch of radial nerve runs downwards between these layers. As the nerve emerges from under the superficial head in the posterior part of forearm, it comes in company with the posterior interosseous artery. For this reason, the nerve is (from this point) called the posterior interosseous nerve. Supinator causes slow and sustained supination, especially when the forearm is extended. Rapid and forceful supination with the forearm flexed is produced by biceps brachii. The fibres of supirator are in a direction antagonistic to those of pronator teres.

Additional Notes on Abductor Pollicis Longus and Extensor Pollicis Brevis (Fig. 17.25)

The abductor pollicis longus and the extensor pollicis brevis are deep to the superficial extensors in the upper part of the forearm. They become superficial by emerging between the extensor carpi radialis brevis and the extensor digitorum. It appears as though these muscles have suddenly sprouted out. For this reason they are referred to as the outcropping muscles of the forearm (or the outcropping muscles of the thumb).

The two muscles are closely related to each other and run laterally and forwards across the tendons of the extensor carpi radialis brevis and longus. They pass under cover of

Table 17.6: Deep muscles of the posterior compartment of forearm

Muscle	Origin	Insertion	Action	Nerve Supply
Supinator	• Lateral epicondyle of humerus • Radial collateral ligament of elbow • Annular ligament • Supinator crest of ulna and posterior part of triangular area in front of it	Upper one-third of lateral surface of radius. (The area extends onto the anterior and posterior aspects of the upper part of the radius)	Supination of the arm	Deep branch of radial nerve (C7, C8)
Extensor pollicis longus	• Lateral part of posterior surface of ulna (below origin of abductor pollicis longus) • Interosseous membrane (adjoining part)	Base of distal phalanx of thumb (dorsal aspect)	• Extends distal phalanx of thumb • Extends proximal phalanx of thumb • Extends first metacarpal • Adduction and lateral rotation of thumb	Deep branch of radial nerve (C7, C8)
Abductor pollicis longus	• Lateral part of posterior surface of ulna. (below insertion of anconeus) • Interosseous membrane (adjoining part) • Posterior surface of radius (below insertion of supinator)	• Radial side of the base of first metacarpal • On trapezium	Abduction and extension of thumb (at carpometacarpal joint of thumb)	Deep branch of radial nerve (C7, C8)
Extensor indicis	• Posterior surface of ulna below origin of the extensor pollicis longus • Interosseous membrane (adjoining part)	Tendon ends by joining the ulnar side of the extensor digitorum tendon for the index finger (and is indirectly inserted into the middle and distal phalanges)	• Extends index finger • Helps to extend the wrist	Deep branch of radial nerve (C7, C8)

contd...

contd ..

Muscle	Origin	Insertion	Action	Nerve Supply
Extensor pollicis brevis	• Posterior surface of radius (below origin of abductor pollicislongus) • Interosseous membrane (adjoining part)	Dorsal surface of the base of the proximal phalanx of the thumb	Extends proximal phalanx and metacarpal bone of the thumb	Deep branch of radial nerve (C7, C8)

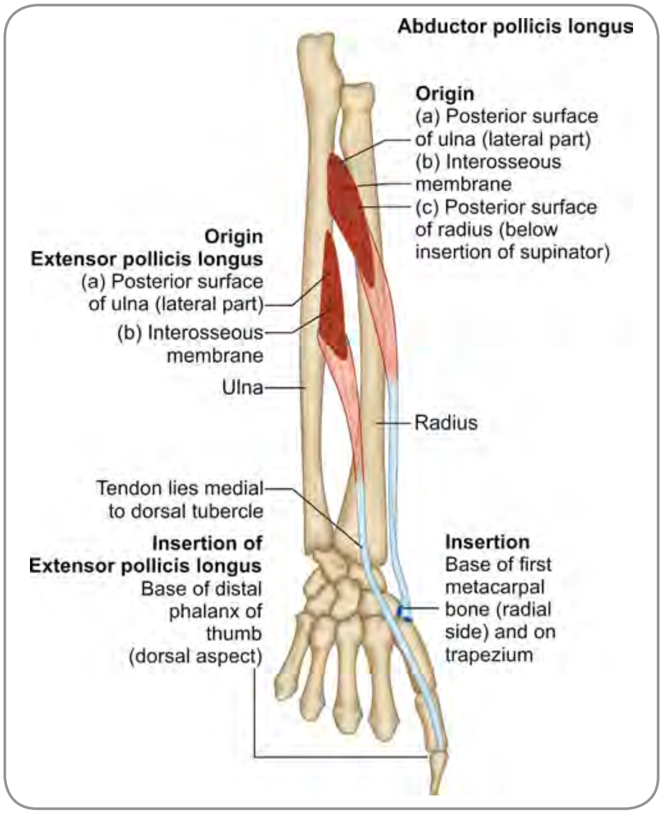


Fig. 17.25: Attachments of extensor pollicis longus and abductor pollicis longus–Some adjoining attachments are also shown for orientation

the extensor retinaculum in the same compartment and within the same synovial sheath.

The outcropping muscles lie on an internervous line. Since no motor nerve will be cut, this line will be the safest line of approach to the back of forearm. This line also divides the superficial muscles of the posterior compartment into a lateral and a posterior group. Approach through this line will also lead to the deeper lying supinator muscle.

Additional Notes on Extensor Pollicis Longus

The extensor pollicis longus is larger and longer than the extensor pollicis brevis (Fig. 17.25). Its tendon passes through a separate compartment of the extensor retinaculum within its own synovial sheath, medial to the dorsal tubercle of radius The tendon uses the tubercle as a pulley to change its line of action. A gap is also created between the two long extensor tendons of the thumb. This gap is the anatomical snuff box.

Anatomical Snuff Box: It is a triangular hollow visible on the lateral aspect of the wrist when the thumb is fully extended. The space is bounded anteriorly by the tendons of abductor pollicis longus and extensor pollicis brevis; posteriorly by the tendon of extensor pollicis longus. The apex of the triangle is directed distally and is the point where the two extensor tendons converge towards each other. Radial artery crosses the floor of the space. Radial styloid process and base of the first metacarpal can be palpated in the proximal and distal parts of the space. Between these two, scaphoid and trapezium can also be palpated. Though the radial artery is the primary content, two other structures are important. The cephalic vein usually commences at the snuff box or very close to it. The dorsal cutaneous branch of radial nerve can be palpated close to the tendon of extensor pollicis longus. When there is fall on an outstretched hand, this space will bear the force. Deep to the snuff box, radius and scaphoid articulate with each other. The force of a fall gets transmitted to these two bones; scaphoid receives more force and is likely to be fractured. Tenderness within the hollow space should raise suspicion about a fractured scaphoid. The radial artery can easily be approached if the cephalic vein and the branch of radial nerve are displaced. The name ***snuff box*** derives from an olden habit of holding ***snuff powder*** in the hollow space when snuff use was popular, the hollow space came in 'handy' and served as a container to hold the snuff powder while the individual would apply a nostril to sniff the snuff. The other names for the anatomical snuff box are ***radial fossa*** and ***tabatiere anatomique*** (tabatiere in French meaning a sachet, sac or container; usually used for the silver brocade snuff container).

Additional Notes on Extensor Indicis

The extensor indicis is a very thin muscle. It gives independence to the index finger; it may act alone or in association with the extensor digitorum; this independence makes it possible for the index finger to be extended when the other fingers are flexed (as in pointing finger) (Fig. 17.26).

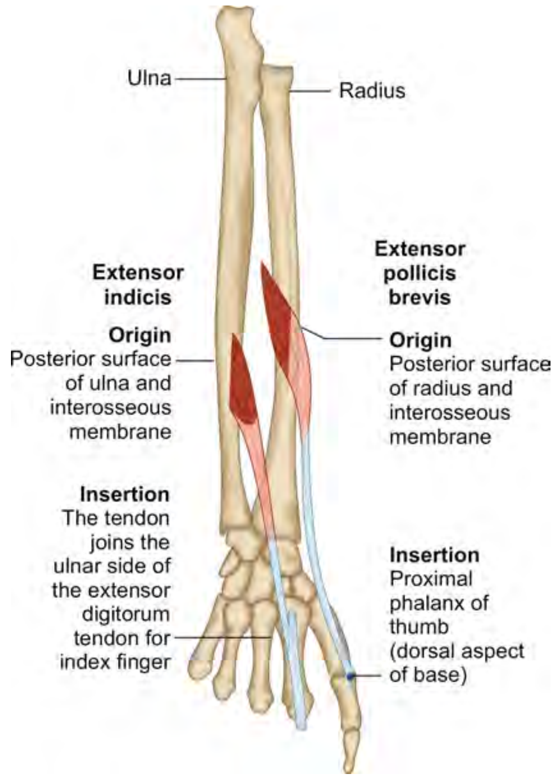


Fig. 17.26: Attachments of extensor indicis and extensor pollicis brevis

Clinical Correlation

- ***Tennis elbow:*** Repeated strain on the extensor muscles of the forearm (as in a tennis player or a violinist) can cause tearing of tissue near the origin of these muscles from the common extensor origin (lateral epicondyle). Pain occurs over the lateral epicondyle and along the radial border of the forearm. This condition is called ***tennis elbow*** or lateral epicondylitis
- A similar condition in relation to the medial epicondyle is called ***golfer's elbow***.
- Sometimes, a strong force can pull a tendon off from its bony attachment (avulse the tendon; the condition is called avulsion). If the tendon of the extensor digitorum (for a digit) is avulsed from its insertion into the distal phalanx, complete extension of the phalanx is no longer possible. The distal phalanx remains in a state of partial flexion. Such a condition is called ***mallet finger*** (mallet = small hammer; the affected finger resembles the shape of a hammer) or ***baseball finger*** (baseball players frequently suffer from this condition due to hyperflexion of the distal interphalangeal joint which leads to the avulsion).
- ***De Quervain's tenosynovitis***: This is a condition where the synovial sheath around the abductor pollicis longus and extensor pollicis brevis tendons is inflamed. Pain and swelling occur in the lateral part of the wrist.

contd...

Clinical Correlation *contd...*

- Blood supply to extensor pollicis longus tendon may be compromised if the artery supplying it (anterior interosseous artery) is injured. Such an injury occurs when the radius is fractured. The tendon ruptures as a result of ischaemia. The patient feels that the thumb has been dropped because extension of the interphalangeal joint is not possible. The resulting deformity is called ***hammer thumb***.
- ***Testing of brachioradialis:*** The elbow is flexed and the forearm kept in midprone position. Flexion of elbow against resistance at this position. A normal muscle can be felt.
- ***Supinator jerk:*** Though called the supinator jerk or the supinator reflex, the muscle involved is brachioradialis Reflex flexion of forearm occurs when the distal reflex is tapped. Brachioradialis is the muscle that contracts.
- ***Testing of extensor carpi radialis muscles:*** After making a fist, the wrist is extended on the radial side against resistance. Normal muscles can be felt close to their insertions
- ***Testing of extensor digitorum:*** The patient is made to place the forearm on the table with the flexor aspect facing inferiorly. The hand is placed palm down with the fingers abducted and spread out. Each metacarpophalangeal joint is extended against resistance.
- ***Testing of extensor carpi ulnaris:*** A closed fist is attempted to be ulnar deviated against resistance.
- ***Testing of abductor pollicis longus:*** Abduction of thumb is performed against resistance. The tendon of the muscle is visibly seen in the margin of the anatomical snuff box.
- ***Testing of extensor pollicis brevis:*** The metacarpophalangeal joint of the thumb is extended against resistance.
- ***Testing of the extensor pollicis longus:*** The interphalangeal joint of the thumb is extended against resistance

Extensor Retinaculum (Fig. 17.27)

The extensor retinaculum is a thickened band of deep fascia of forearm (antebrachial fascia) that extends across the back (and sides) of the wrist. It is about 2.5 cm in width and forms an obliquely transverse band over the distal end of radius and the medial carpal bones. It holds the extensor tendons in place and facilitates their action by acting as a pulley.

Fig. 17.27: Attachments of extensor retinaculum

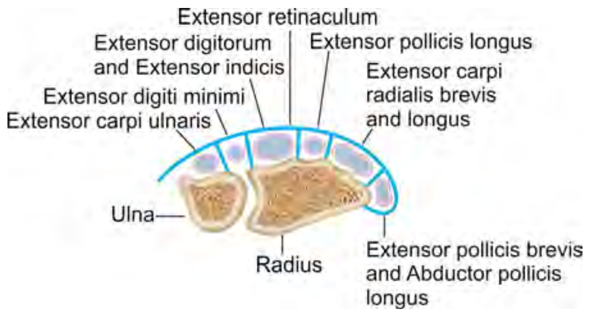


Fig. 17 28: Tendons passing under cover of extensor retinaculum

The retinaculum sends septa to the radius and the medial carpal bones thereby forming osseofibrous tunnels for the extensor tendons to pass through. Because of these septa, the space between the deep surface of the retinaculum and the underlying bones is divided into six compartments.

There are tendons of nine muscles passing under cover of the extensor retinaculum; these pass through in six compartments The distribution of the tendons in the compartments is as follows (Fig. 17.28):

- ***Compartment 1:*** Extensor pollicis brevis and abductor pollicis longus;
- ***Compartment 2:*** Extensor carpi radialis longus and extensor carpi radialis brevis;
- ***Compartment 3:*** Extensor pollicis longus;
- ***Compartment 4:*** Extensor digitorum and extensor indicis;
- ***Compartment 5:*** Extensor digiti minimi;
- ***Compartment 6:*** Extensor carpi ulnaris.

Synovial Sheaths of the Tendons (Fig. 17.29)

The tendons passing under the extensor retinaculum are surrounded by synovial sheaths. Normally, there are six sheaths—one each for the tendons passing through each compartment under the extensor retinaculum. However, the tendons of the first compartment (i.e. the abductor pollicis longus and the extensor pollicis brevis) and those of the second compartment (i.e. extensor carpi radialis longus and extensor carpi radialis brevis) may have individual sheaths. Proximally, the sheaths extend for a short distance proximal to the extensor retinaculum. Distally, the sheaths of tendons that gain insertion into the bases of the metacarpal bones extend up to the insertion. The sheath for the extensor pollicis brevis extends to the base of the first metacarpal bone The sheaths for the tendons going to the digits, and that for the extensor pollicis longus, extend to the level of the middle of the metacarpus.

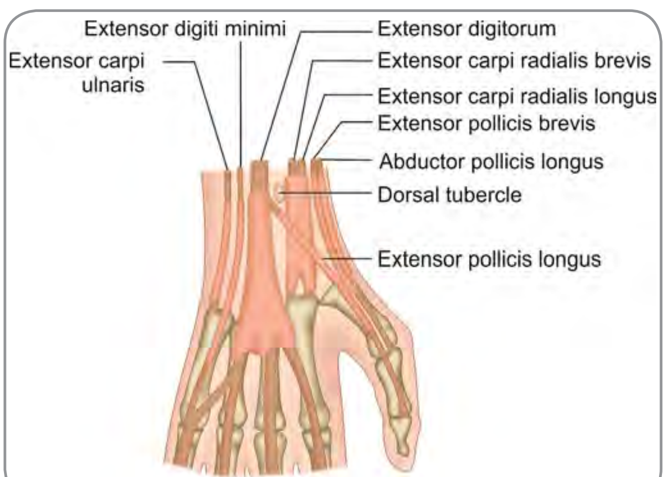


Fig. 17.29: Synovial sheaths on the dorsum of wrist and hand

Clinical Correlation

Infection of the synovial sheaths of the extensor tendons is not common. However, repeated stress can lead to inflammation of one or more sheaths (***tenosynovitis***) in which there can be pain and restriction of movement. The tendons of the abductor pollicis longus and the extensor pollicis brevis rub constantly against the styloid process of the radius The common synovial sheath around them may undergo fibrosis (***stenosing tenosynovitis***) restricting movement and may require incision of the sheath.

Added Information

- The brachioradialis developmentally belongs to the extensor group and so is supplied by the extensor nerve; but it behaves like a flexor.
- Developmentally, the anconeus is an extension of the triceps.

VESSELS AND NERVES OF FOREARM AND HAND

The muscles of the forearm are grouped into those of the anterior and the posterior compartments. The muscles of the anterior compartment extend into the palm and those of the posterior compartment extend into the dorsum However, the vessels and nerves of the region cannot be totally subdivided and there is considerable overlap in their course and distribution (Fig. 17.30).

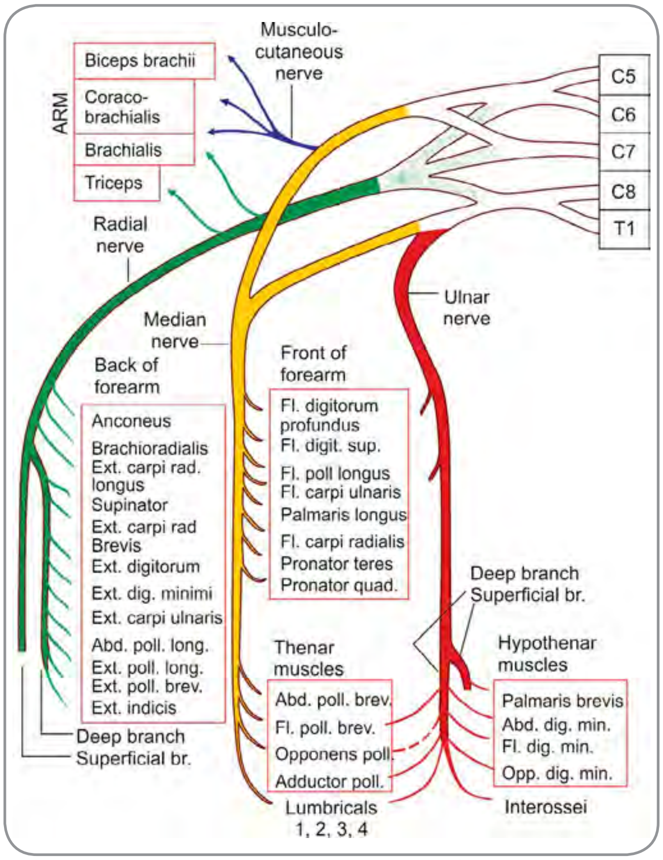
Vessels of Forearm and hand

The arteries of the forearm are the ulnar and radial arteries which arise in the cubital fossa as terminal branches of the brachial artery. Various branches of the ulnar and radial arteries provide blood supply to the forearm and hand.

The veins of forearm are grouped into the superficial and deep veins.

Arteries of Forearm and Hand

Ulnar artery: The ulnar artery arises as the larger terminal branch of the brachial artery in the lower part of the cubital



F g. 17.30: Scheme to show the nerve supply of various muscles of the arm, forearm and hand

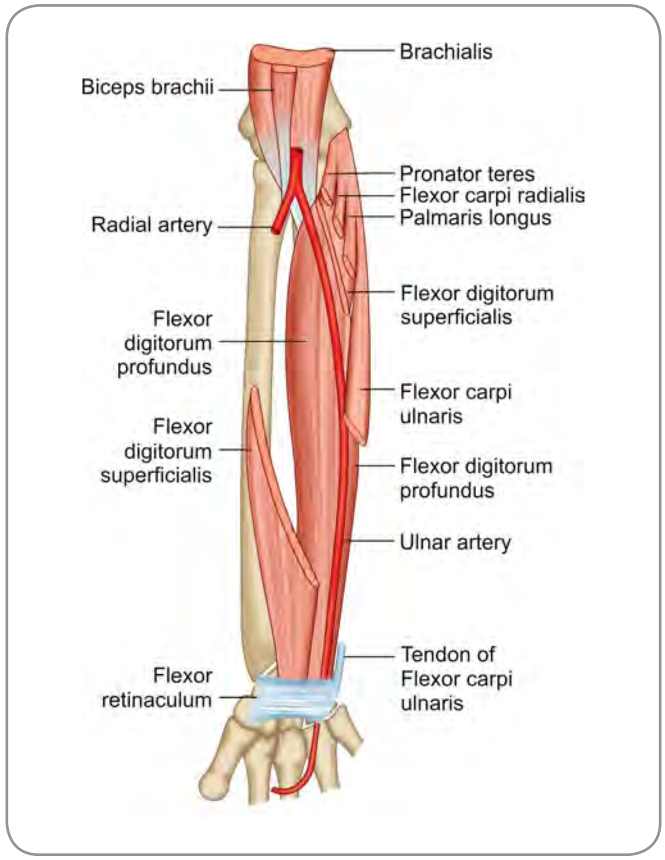


Fig. 17.31: Relations of the ulnar artery

fossa, opposite the neck of radius; it ends in the palm. It runs the major part of its course in the forearm.

Course: Starting from the brachial artery, the ulnar artery runs first downwards and medially (proximal one third) and then downwards (distal two-thirds), deep to the superficial and intermediate layers of the flexor muscles to reach the medial side of the front of forearm. As it changes course from the inferomedial to inferior direction at about the junction of the proximal third and the distal two-thirds of the forearm, it comes into relation with the ulnar nerve. It then, along with the nerve, passes superficial to the flexor retinaculum to enter the hand Having reached the radial aspect of the pisiform bone, it ends by dividing into the deep palmar branch and the superficial palmar arch.

Relations (Fig. 17.31)

- ***Anteriorly:***
  - ***Proximal third:*** The artery is crossed by (from above downwards) pronator teres, median nerve, flexor carpi radialis, palmaris longus and flexor digitorum superficialis.
  - ***Middle third:*** It is overlapped by the flexor carpi ulnaris.
  - ***Distal third:*** It is covered by fasciae and skin.
  - ***While on the flexor retinaculum:*** It s covered by the superficial part of the flexor retinaculum that attaches to the pisiform bone.
- ***Posteriorly:*** Brachialis and flexor digitorum profundus; at the wrist region, flexor retinaculum is the posterior relation.
- ***Laterally (radial side):*** (especially in the distal two thirds) flexor digitorum superficialis.
- ***Medially (ulnar side):*** Flexor carpi ulnaris and ulnar nerve.

The ulnar artery is accompanied by its venae comitantes throughout its length.

Branches (Fig. 17.32)

The branches of the ulnar artery supply the muscles of the central and medial areas of the forearm, the ulnar and the median nerves.

- ***Anterior ulnar recurrent artery:*** This branch arises in the cubital fossa, immediately distal to the elbow joint; it then runs upwards passing between the pronator teres and the brachialis, supplying both the muscles; reaching the front of medial epicondyle, it anastomoses with the inferior ulnar collateral artery (a branch of the brachial artery).

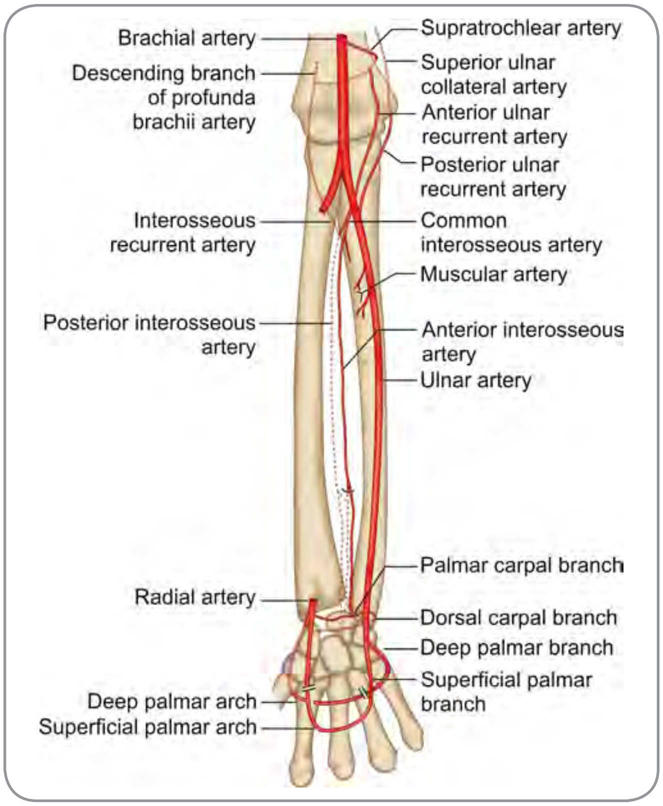


Fig. 17.32: Scheme to show branches of the ulnar artery

- ***Posterior ulnar recurrent artery:*** This branch arises in the cubital fossa distal to the previous branch; being larger than the anterior ulnar recurrent artery, it runs upwards on the flexor digitorum profundus muscle; reaching the posterior aspect of the medial epicondyle, it passes deep to the flexor carpi ulnaris to anastomose with the superior ulnar collateral artery (a branch of brachial artery).
- ***Common interosseous artery:*** This branch arises in the cubital fossa, usually close to the point of origin of the parent artery; it is a short trunk that immediately passes backwards towards the superior border of the interosseous membrane; it divides into the anterior and posterior interosseous branches.
  - ***Anterior interosseous artery:*** This is a branch of the common interosseous artery arising between the ulna and the radius; along with the anterior interosseous nerve, it descends on the anterior surface of the interosseous membrane between the flexor digitorum profundus medially and the flexor pollicis longus radially to the superior border of pronator quadratus; it then pierces the membrane to reach the dorsal aspect; it further continues down on the posterior surface of the interosseous membrane and the dorsal aspect of radius; it ends by joining the dorsal carpal arch that lies on the posterior aspec of the distal end of the interosseous membrane; the anterior interosseous artery gives out muscular branches, nutrient branches to ulna and radius, a thin communicating branch to the palmar carpal arch and the median artery; the median artery is given out from the proximal aspect of the anterior interosseous artery and accompanies the median nerve to the palm.
  - ***Posterior interosseous artery:*** This is a branch of the common interosseous artery arising between the ulna and the radius; it passes between the interosseous membrane and the oblique cord to reach the posterior aspect; it descends initially between the supinator and the abductor pollicis longus, then between the superficial and the deep extensor muscles to anastomose with the anterior interosseous artery and the dorsal carpal arch. When the artery crosses the abductor pollicis longus, it is accompanied by the posterior interosseous nerve, but in the rest of the course, it is separated from the nerve by the deep extensor muscles; the posterior interosseous artery gives off muscular branches and a recurrent interosseous artery; the recurrent interosseous artery branches off the posterior interosseous artery in the latter's upper portion between the ulna and the radius, passes superolaterally to reach the lateral epicondyle and anastomoses with the middle collateral artery (a branch of the profunda brachii).
- ***Palmar carpal artery:*** This branch arises at the wrist; it passes deep to the flexor tendons, anastomoses with the palmar carpal branch of the radial artery and completes the palmar carpal arch.
- ***Dorsal carpal artery:*** This small branch arises near the pisiform bone; it passes deep to the tendons of flexor and extensor carpi ulnaris muscles to reach the dorsal aspect and join the dorsal carpal arch.
- ***Deep palmar artery:*** This branch arises near the pisiform bone; it runs between the hypothenar muscles, turns laterally deep to the long flexor tendons, joins the radial artery and completes the deep palmar arch.

Surface anatomy: (In the forearm) The course of the ulnar artery in the forearm can be marked on the surface in two parts.

The proximal one-third can be marked as the oblique part. Point A is marked 1 cm below the midpoint of the inter epicondylar line. Point B is marked at the junction of the upper one-third with the lower two-thirds of the line connecting the medial epicondyle and the pisiform. The two points are connected by a line. This indicates the oblique part of the ulnar artery.

The distal two-thirds of the ulnar artery in the forearm is marked by the vertical part. Point A is marked at the lower end of the oblique part (or the point at the junction of the upper one-third with the lower two-thirds of the line joining the medial epicondyle and the pisiform). Point B is marked at the pisiform bone. The two points are joined by a line which represents the vertical part of the ulnar artery.

Clinical Correlation

- The ulnar artery is deeply placed and so it is not possible to feel the ulnar pulse. The artery is used to arterialize the basilica vein; a communication is created between the artery and the vein. This procedure is of help in dialysis therapy in chronic renal failure patients.
- The ***ulnar artery*** can be compressed immediately lateral to the pisiform bone.
- When the ulnar artery arises at a higher level than usual, it may pass superficial to the muscles.
- The median artery may be larger than usual; in such a case, the digital arteries arise from the median artery.

Radial artery: The radial artery arises as the smaller terminal branch of the brachial artery in the lower part of the cubital fossa, opposite the neck of radius; it ends in the palm by forming the deep palmar arch. It is more in line with the parent trunk than the ulnar artery.

Course: The radial artery is divided into three parts (Fig. 17.33).

- ***First part:*** This is the part of the artery from its origin to the level of the styloid process of the radius; this is the part of the artery in the forearm;
- ***Second part:*** This is the part that curves around the lateral aspect of the wrist to reach the proximal end of the first interosseous space;
- ***Third part:*** This is the part that passes through the first interosseous space to reach the palm of the hand.

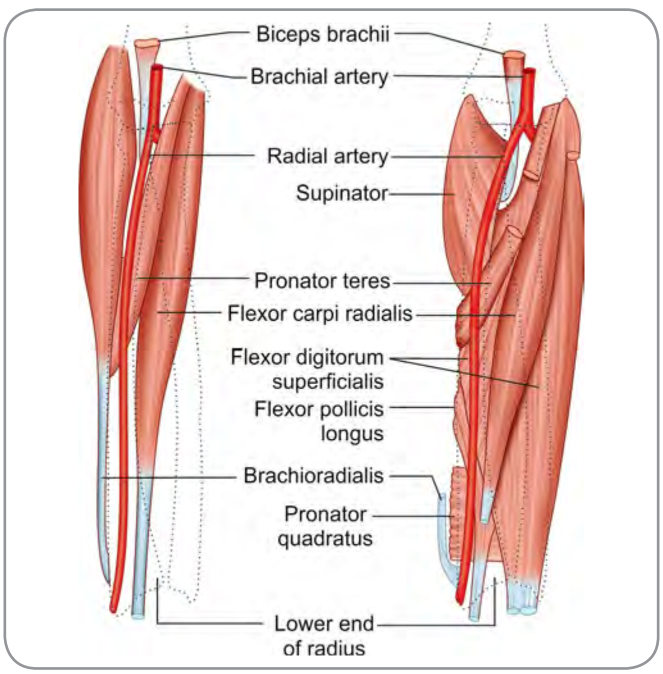


Fig. 17.33: Muscles related to the radial artery

Relations of the First Part

- ***Anteriorly:*** It is overlapped by the brachioradialis in its proximal half; and covered by fasciae and skin in the distal half.
- ***Posteriorly:*** (From above downwards) tendon of biceps, supinator, pronator teres, flexor digitorum superficialis, flexor pollicis longus, pronator quadratus and anterior aspect of lower part of radius.
- ***Laterally (radial side):*** Brachioradialis in the proximal third and superficial branch of radial nerve in the middle third.
- ***Medially (ulnar side):*** Pronator teres proximally and the flexor carpi radialis distally.
- The artery is accompanied by it venae comitantes throughout its course.

Branches of the First Part

- ***Radial recurrent artery:*** This branch arises from the radial artery in the cubital fossa, on the surface of supinator; running upwards it reaches the lateral epicondyle to anastomose with the radial collateral artery (a branch of the profunda brachii).
- ***Muscular branches:*** These are several branches to muscles on the radial aspect of forearm.
- ***Superficial palmar artery:*** This slender branch arises just above the wrist and runs across the base of the thumb; piercing the thenar muscles, it either ends by supplying them or by completing the superficial palmar arch.
- ***Palmar carpal artery:*** This branch arises at the distal border of pronator quadratus; it runs deep to the flexor tendons to anastomose with the palmar carpal branch of the ulnar artery to form the palmar carpal arch.

Relations of the Second Part

- ***Superficial:*** As the radial artery curves around, it is crossed by the tendons of abductor pollicis longus, extensor pollicis brevis and the extensor pollicis longus and the cephalic vein.
- ***Deep:*** The artery runs on the radial collateral ligament, scaphoid and trapezium.

Branches of the Second Part

- ***Dorsal carpal artery:*** This branch arises when the radial artery is winding around the lateral aspect of the hand; it joins with the corresponding branch of the ulnar artery to form the dorsal carpal arch; from this arch, three dorsal metacarpal arteries arise and run

distally; opposite the heads of the metacarpal bones, each dorsal metacarpal artery divides into two dorsal digital arteries; these arteries supply the adjacent sides of the 2nd and 3rd, the 3rd and 4th and the 4th and 5th digits.

- ***Dorsal digital arteries of thumb*** and
- ***Dorsal digital artery to the radial side of index finger:*** Two dorsal digital arteries, one each to the radial and ulnar sides of the thumb and one dorsal digital artery to the radial side of the index finger take independent origin from the radial artery.

Relations of the Third Part

The artery passes first between the heads of the first dorsal interosseous muscle, then between the heads of the Adductor pollicis and unites with the deep branch of the ulnar artery to complete the deep palmar arch.

Branches of the Third Part

- ***Princeps pollicis artery:*** This branch is given out where the main radial artery enters the palm; it courses distally under cover of the long flexor tendons; it then divides into two palmar digital arteries which run along the sides of the thumb and anastomose with the palmar digital arteries.
- ***Radialis indicis artery:*** This small branch is given out immediately after the princeps pollicis; it runs distally along the radial border of the index finger.

Surface anatomy: The radial artery can be marked on the surface in the forearm and as it winds around to the dorsal aspect. Point A is marked 1 cm below the midpoint of the interepicondylar line. Point B is marked at the radial pulse (proximal to wrist). Point C is marked immediately above the tubercle of the scaphoid. The three points are joined by a line that represents the course of the artery in the forearm. The artery winds around above the scaphoid tubercle and below the tip of the styloid process of radius.

The radial pulse is usually felt proximal to the wrist. It can be found lateral to the tendon of flexor carpi radialis longus and against the anterior surface of the lower part of radius.

Clinical Correlation

- Radial pulse is the most common parameter felt and measured while examining a patient. It is felt superficial and is easily accessible in a commonly exposed part of the body.
- The radial artery in its superficial location is chosen for arterial punctures (occasions like drawing arterial blood for blood gas analysis).
- The radial artery is also used for arterial grafts (in procedures like coronary artery bypass grafting).
- The ***radial artery*** can be compressed where it lies over the anterior surface of the lower end of the radius.

contd...

Clinical Correlation *contd...*

- The radial artery may arise from the axillary artery; in such a case, it may lie superficial to the extensor tendons. Variations in the position of the radial artery may make palpation of the radial pulse difficult. In such cases, pulse can be attempted to be felt in the other limb because bilateral variation is rare.

Developmental factors: Vascular plexuses develop in different parts of the upper limb buds as happens in other parts of the body. Soon, the dorsal aorta develops and conducts blood from the heart to different parts via intersegmental arteries. About four or five inte segmental arteries opposite the level of the upper limb buds lengthen and extend into the buds; they gradually get connected to the vascular plexuses and start supplying them. Early in development, the lateral branch of the seventh cervical intersegmental artery becomes enlarged and develops into the axial artery of the upper limb. This axis artery extends through the entire length of the developing limb and ends in the distal most vascular plexus. Vascular plexuses in the more proximal portions of the limb bud consolidate into branches of the region. The distal most plexus gives rise to the palmar arches and the digital branches. The proximal part of the axis artery is the brachial artery and the distal portion is the interosseous artery. The radial and the ulnar arteries arise out of the middle portion of the axis artery and extend as new vessels much later in development. Still later, the radial and ulnar vessels connect with the palmar plexuses.

Arteries of the Palm of Hand

The hand requires an abundance of blood supply because of the multiple positions in which it would be held; and many of these positions result in pressure being applied on different parts of the hand. Therefore, the arteries of the hand are highly branched and form a dense network, so that blood is available to all parts in all positions. Blood to the hand is derived from branches of the ulnar and the radial arteries.

The ***ulnar artery*** enters the hand superficial to the flexor retinaculum Lying lateral to the ulnar nerve, it divides into its two terminal branches—the superficial palmar arch and the deep palmar branch.

The ***superficial palmar arch*** can be considered the main continuation of the ulnar artery. It curves laterally deep to the palmar aponeurosis and superficial to the long flexor tendons. It joins with the superficial branch (or any other branch) of the radial artery on the lateral side and the arch is thus completed. The superficial palmar arch, from its convexity, gives rise to three common palmar digital arteries which anastomose with the palmar metacarpal arteries given out by the deep palmar arch. It also gives a separate branch to the medial side of the little finger.

The ***radial artery*** from the dorsal side curves around the lateral aspect of the wrist and runs on the floor of

the anatomical snuff box. It enters the palm by passing between the two heads of the first dorsal interosseous muscle; then turns medially to pass between the heads of adductor pollicis; it ends by anastomosing with the deep palmar branch of the ulnar artery to form the deep palmar arch.

The ***deep palmar arch*** lies deep to the long flexor tendons and in contact with the bases of the metacarpals. It gives rise to three palmar metacarpal arteries which join the three common palmar digital arteries of the superficial palmar arch. The deep palmar arch gives four proximal perforat ng arteries which passes dorsally to join the dorsal metacarpal arteries.

The three ***common palmar digital arteries***, formed by the union of the branches of ulnar and radial arteries, run distally on the lumbricals to the webs of the 2nd and 3rd, the 3rd and 4th and the 4th and 5th digits. At the interdigital clefts in the webs, each common palmar digital artery divides into a pair of proper palmar digital arteries which run along the adjacent sides of the 2nd and 3rd, the 3rd and 4th and the 4th and 5th digits (i.e. the index and middle, the middle and ring and the ring and little fingers). Immediately before bifurcating, each common palmar digital artery gives out a distal perforating branch that passes dorsally to join the dorsal perforating artery.

As already seen, the two sides of the thumb are supplied by the princeps pollicis artery and the lateral side of the index finger by the radialis indicis artery.

Surface anatomy: (In the forearm) Point A is marked opposite the neck of radius immediately medial to the tendon of biceps. Point B is marked exactly on the pulsation of the artery on the anterior surface of lower part of radius. Points A and B are jointed by a line slightly curved to the lateral side.

Added Information

- The princeps pollicis and the radialis indicis arteries usually arise by a common stem. This common stem, if present, is referred to as the 'first palmar metacarpal' artery (in line with the other palmar metacarpal arteries given out by the deep palmar arch formed predominantly by the radial artery).
- ***Carpal rete:*** Though there are two carpal arches (palmar and dorsal), it is the dorsal carpal arch which is referred to the carpal rete. It is also known as the dorsal carpal network or the posterior carpal arch or the rete carpale dorsale. It is formed across the dorsal aspect of the wrist by anastomosis of the dorsal carpal branch of the radial artery and the dorsal carpal branch of the ulnar artery. The arch is reinforced by branches from the anterior and posterior interosseous arteries; with several arterial twigs contributing to it the arch appears more like a network and hence the name rete (Latin. Rete=network). Three dorsal metacarpal arteries arise from the rete; each dorsal metacarpal artery runs distally

contd...

Added Information *contd...*

to reach its corresponding interdigital space and divide into two dorsal digital arteries; these dorsal digital arteries supply the adjacent sides of the 2nd and 3rd, the 3rd and 4th and the 4th and 5th digits.

- ***Palmar carpal arch:*** This is an arterial network seen on the ventral aspect of the wrist. It is formed across the ventral aspect of the wrist by the union of the palmar carpal branch of the radial artery and the palmar carpal branch of the ulnar artery. It is reinforced by a branch from the anterior interosseous artery and recurrent branches from the deep palmar arch. Branches arising from the palmar carpal arch supply the joints of the wrist.

Clinical Correlation

- ***Arterial anastomoses:*** Numerous arterial anastomoses are present in the hand, the largest of these being between the radial and ulnar arteries through the superficial and deep palmar arches. They serve as efficient communication channels in the event of blockage or ligature of one artery.
- ***Gangrene and ulceration:*** Blockage of the arterial supply to the distal part of a limb can result in death of tissues within that part. Such a part loses all functions and gradually changes colour finally becoming black. This condition is called ***gangrene***. Such a part has to be removed by amputation. Gangrene of the fingers can occur as a result of exposure to extreme cold. It may also be caused by some drugs. Sometimes a gangrenous part may become infected. This makes the condition much more serious. Ischaemia of a region can also lead to ***localised necrosis*** of tissue and ulcers may form.
- ***Raynaud's disease*** (or ***phenomenon):*** In all persons, exposure to cold can cause ***vasoconstriction***. In some persons, this response is abnormally high and vasoconstriction of arterioles in the distal part of the limb may seriously impair blood supply to the hands. In such cases, a series of events may be observed. When the hand is cooled first, there is a loss of colour (***blanching***) and the hand becomes pale. After an interval, the arterioles dilate and blood starts flowing into the hand, but this blood is deoxygenated (because of stagnation in arteries). The hand becomes swollen and dark. As more blood flows into the hand the deoxygenated blood is washed off (with oxygenated blood) and the hand becomes red in colour. Basically the condition is caused by abnormally active sympathetic nerves. It can be controlled with drugs. In more severe cases, ***sympathetic denervation*** of blood vessels of the limb is necessary. This can be achieved by surgical removal of the upper thoracic sympathetic ganglia (preganglionic cervico-dorsal sympathectomy).
- ***Injury to palmar arches:*** A wound injuring one of the palmar arches causes severe bleeding and is difficult to treat. As the arches receive blood from both the radial and ulnar arteries, the injured arch bleeds from both ends. Compression or ligation of the radial or ulnar artery cannot control bleeding. Compression of the brachial artery may be necessary.

Veins of Forearm and Hand

As already noted, the veins of forearm fall into two groups—the superficial and the deep The superficial veins are those present in the superficial fascia and are part of the superficial system of veins of the upper limb.

The deep veins are the venae comitantes of the various arteries and their tributaries. The radial and ulnar venae comitantes arise from the deep palmar venous arch. From the radial side of the arch arise two veins which form the radial venae comitantes and from the ulnar side arise two veins which form the ulnar venae comitantes. Throughout their course, the venae comitantes of each artery anastomose freely with each other. As they ascend in the forearm, they receive tributaries from several muscles of the region. The interosseous venae comitantes arise from the venules of the region and accompany the anterior and posterior interosseous arteries. The interosseous venae comitantes join the radial and ulnar venae comitantes which in turn join the brachial venae comitantes.

The deep veins, in the region of the cubital fossa, are connected to the median cubital vein by intercommunicating veins.

Nerves of Forearm and Hand

The muscles and other tissues of forearm are supplied by the derivatives of the three cords of the brachial plexus, namely, the median (predominantly lateral cord), the ulnar (medial cord) and the radial nerve (posterior cord). The median nerve, the ulnar nerve and the superficial branch of the radial nerve can be regarded as nerves of the anterior compartment of forearm and palm of hand while the posterior interosseous nerve (deep branch of the radial nerve) can be called the nerve of the posterior compartment of forearm and dorsum of hand.

Median Nerve

The median nerve is formed by the union of lateral and medial roots that arise from the corresponding cords of the brachial plexus. Its upper portion lies in the axilla, lateral to the axillary artery. It continues into the arm lateral to the brachial artery. Near the middle of the arm, it crosses superficial to the artery to reach its medial side, and descends in this position to the cubital fossa. It leaves the cubital fossa by passing between the superficial and deep heads of the pronator teres.

The nerve runs down the forearm in the plane between the flexor digitorum superficialis and the flexor digitorum profundus. At the wrist, it lies between the tendons of the flexor digitorum superficialis (medially) and the flexor carpi radialis (laterally). It then enters the hand by passing deep to the flexor retinaculum, immediately distal to the retinaculum, the nerve spreads out and separates into all its branches in the palm (Fig. 17.34).

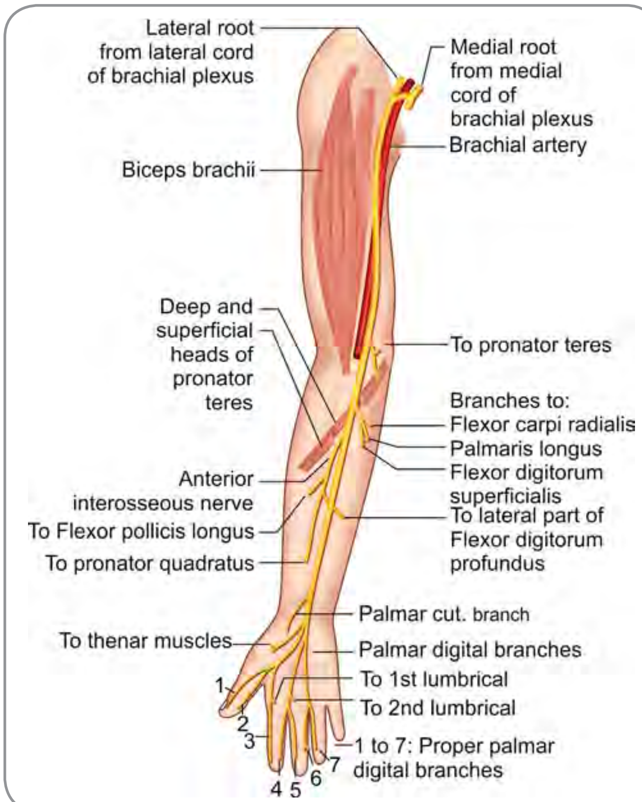


Fig. 17.34: Scheme to show the course and branches of median nerve

Branches in the Forearm

The median nerve is the principal nerve of the anterior compartment of the forearm. Though it has no branches in the arm (except for a few twigs to the brachial artery), it gives out many branches in the forearm. The major branch in the forearm is the anterior interosseous nerve. The other branches are unnamed and include muscular, articular and cutaneous branches

The ***anterior interosseous nerve*** arises from the median nerve as the latter passes between the two heads of the pronator teres. It runs down the forearm in front of the interosseous membrane in company with the anterior interosseous branch of the ulnar artery. After supplying the flexor pollicis longus and the lateral part of the flexor digitorum profundus, it passes deep to pronator quadratus and supplies it too. It then ends by supplying articular twigs to the radiocarpal, inferior radioulnar and intercarpal joints.

Muscular Branches

- The nerve to pronator teres arises at or near the elbow and enters the muscle on its lateral border.
- A broadband of nerves, arising in the upper part of the forearm, passes superficially to supply the flexor carpi radialis, the palmaris longus and the flexor digitorum superficialis.

Articular Branches

Tiny twigs from the median nerve or its muscular branches supply the elbow joint and the superior radioulnar joint.

Cutaneous Branches

The ***palmar cutaneous branch*** arises in the lower part of the forearm, pierces the deep fascia, reaches the superficial fascial plane and passes into the hand superficial to the flexor retinaculum. It supplies the skin over the thenar eminence and over the middle of the palm. It may not always be present.

Branches in the Hand

Reaching the palm by traversing under cover of the flexor retinaculum, the median nerve immediately divides into several branches; these branches supply the skin, muscles and joints of the palm and hand.

Muscular Branches

- The main muscular branch passes to the base of the thenar eminence and supplies the thenar muscles namely—the flexor pollicis brevis, the abductor pollicis brevis and the opponens pollicis.
- The first and second lumbrical muscles of the hand are supplied by branches from the palmar digital nerves.

Articular Branches

Twigs from the palmar digital nerves supply the metacarpophalangeal and interphalangeal joints of the thumb, index, middle and sometimes the ring fingers.

Cutaneous Branches

Among the terminal branches of the median nerve are the ***palmar digital nerves*** which are usually five in number. The lateral three continue as ***proper palmar digital nerves,*** two of them supplying the lateral and medial sides of the thumb (these are called the first and second proper palmar digital nerves respectively) and the third supplying the lateral side of the index finger (this is called the third proper palmar digital nerve). The other two divide (these are called the lateral and medial common palmar digital nerves respectively) at the clefts between the index and middle and the middle and ring fingers into the proper palmar digital nerves which supply the adjacent sides of the respective fingers.

The common palmar digital nerves are under cover of the palmar aponeurosis between the superficial palmar arch and the flexor tendons. Reaching close to the roots of fingers, they become superficial; the proper palmar digital nerves to the thumb and the digital nerve to the lateral side of the index finger reach the superficial plane at the lateral border of the palmar aponeurosis; the other digital nerves reach the superficial plane in the gaps between the slips of palmar aponeurosis. Through these branches the median nerve supplies the palmar surface of the lateral three and a half digits. The palmar digital branches give out one or two dorsal branches which get distributed to the skin and fascia (including the nail bed) on the dorsal aspect of the distal phalanx of the thumb and the distal two phalanges of the index, middle and lateral half of ring fingers. In the fingers, the digital nerves lie in front of the palmar digital arteries.

Surface Anatomy

Median nerve (in the forearm): Point A is marked at the level of the neck of radius in the midline of the limb (grossly, about 1 cm beyond the bend of elbow on the midline). Point B is marked at the wrist about 1 cm medial to the tendon of flexor carpi radialis A line joining the two points indicates the median nerve in the forearm.

Clinical Correlation

Effects of Injury to the median nerve: The effects of injury to the median nerve vary depending upon the level of injury, the effects being confined to structures supplied by branches distal to the injury. ***Muscles supplied by the nerve and its branches may be paralysed*** and the effects thereof are as follows:

Muscles paralysed	Effects
Flexor carpi radialis	Flexion and abduction of the wrist are weak. Unopposed action of the flexor carpi ulnaris adducts the hand when flexion is attempted.
Pronator teres and pronator quadratus	Power of pronation is lost. However, the brachioradialis (supplied by the radial nerve) can bring the forearm to the midprone position.
Flexor digitorum superficialis* and lateral part of the *flexor digitorum profundus	Middle phalanges cannot be flexed—all fingers are affected. Because of the paralysis, the terminal phalanges of the index and middle fingers cannot be flexed. Those of the ring and little fingers can be flexed because the medial part of the muscle is supplied by the ulnar nerve. The proximal phalanges can be flexed by the interossei (supplied by the ulnar nerve).
Flexor pollicis longus	The thumb cannot be flexed at the interphalangeal joint.
Thenar muscles	The thumb cannot be abducted or opposed at the carpometacarpal joint; it remains in a position of extension (produced by the extensor pollicis longus) and adduction (produced by the adductor pollicis). This is referred to as an ***ape-like*** hand

contd...

Clinical Correlation *contd...*

Depending on the level of lesion and the branch involved, all or some of the above mentioned effects can be seen. There will be ***sensory loss*** in the area supplied by the median nerve.

- Digital branches of the median nerve supply the 1st and 2nd lumbrical muscles. When these muscles are paralysed, flexion of the metacarpophalangeal joints of the index and middle fingers is lost. When 'making a fist' is attempted, index and middle fingers remain in partial extension leading to the 'position of benediction' of the hand.
- ***Anterior interosseous Nerve syndrome:*** Muscles supplied by the anterior interosseous nerve are paralysed These are the flexor pollicis longus, pronator quadratus and that part of flexor digitorum profundus giving tendons to the index and middle fingers. There is difficulty in bringing the tips of the thumb and the index finger together. When the patient tries to do so, the enti e length of the terminal phalanx of the index finger is brought against the terminal phalanx of the thumb, thus resulting in the formation of a triangle. This is usually described as 'doing the triangular sign' (terminal phalanges together) instead of 'doing the OK sign' (tips together). Flexion of distal interphalangeal joints of index and middle fingers is affected. Pinching action is lost; patient has difficulty in picking up objects.
- ***Carpal tunnel syndrome:*** Carpal tunnel is a passage between the carpal bones and the flexor retinaculum. Most of it is occupied by the flexor tendons and their synovial sheaths. The median nerve passes through the tunnel. Any increase in the volume of contents of the tunnel can compress the median nerve. This may occur because of inflammation in the synovial sheaths (usually the ulnar bursa). Pressure on the nerve gives rise to burning pain in the lateral three and a half digits. Skin over the thenar eminence is spared because it is supplied by the palmar cutaneous branch of the median nerve that arises above the level of the flexor retinaculum and descends superficial to it. The carpal tunnel syndrome can be treated by incising the flexor retinaculum.
- The branch to the thenar muscles runs on the base of the thenar eminence before submerging into the muscles. The deep fascia of the thenar eminence is very thin and so the nerve is practically unprotected here. Any injury in this area can damage the nerve.

Ulnar Nerve

The ulnar nerve is a branch of the medial cord of the brachial plexus. It extends from the axilla to the hand. At its origin, it lies medial to the axillary artery (between it and the axillary vein). It runs down the front of arm where it lies medial to the brachial artery. At the middle of the arm, the nerve passes into the posterior compartment by piercing the medial intermuscular septum and descends (in company with the ulnar collateral artery) between this septum and the lower part of the triceps (medial head) (Fig. 17.35). Passing medially as it descends, it passes behind the medial epicondyle of the humerus. The nerve enters the forearm by passing deep to the tend nous arch joining

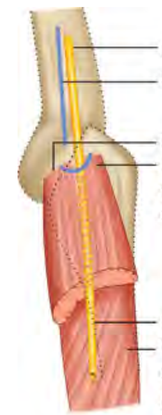


Fig. 17.35: Ulnar nerve entering the forearm by passing deep to the tendinuous arch connecting the humeral and ulnar heads of flexor carpi ulnaris

the humeral and ulnar heads of the flexor carpi ulnaris. It then runs down the medial side of the front of forearm lying superficial to the flexor digitorum profundus. In the lower two-thirds of the forearm the nerve is accompanied by the ulnar artery which lies lateral to it. In the upper part of the forearm, the nerve is deep to the flexor carpi ulnaris and to the flexor digitorum superficialis. Becoming superficial in the lower one-third of the forearm, it lies between the tendons of flexor carpi ulnaris (medially) and flexor digitorum superficialis (laterally).

The nerve enters the hand by passing superficial to the flexor retinaculum, lying in a groove on the lateral aspect of the pisiform bone. It then divides into its two terminal branches, the superficial and the deep branches. The ulnar nerve is distributed to skin, muscle and joints through its various branches (Figs 17.36 and 17.37).

Branches in the Forearm

Similar to the median nerve, the ulnar nerve also does not usually give out any branch in the arm. In the forearm, it gives out muscular, articular and cutaneous branches.

Muscular Branches

These arise as soon as the ulnar nerve enters the forearm. Two branches to flexor carpi ulnaris and one to the medial part of flexor digitorum profundus are given out.

Articular Branches

A single articular branch arises as the nerve passes behind the medial epicondyle and gets distributed to the posterior aspect of the elbow joint.

Cutaneous Branches

Two cutaneous branches are given out.

- The ***palmar cutaneous branch*** arises near the middle of the forearm. Piercing the deep fascia in the distal

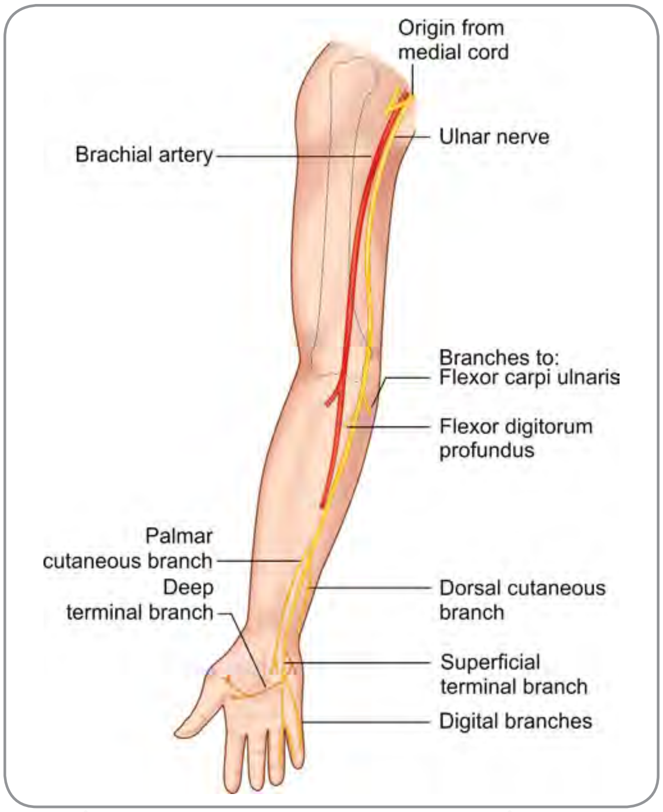


Fig. 17.36: Scheme showing the course and branches of the ulnar nerve

forearm and becoming superficial, it passes to the medial side of palm and supplies the skin of the area.

- The ***dorsal cutaneous branch,*** larger of the two cutaneous branches, arises from the ulnar nerve a little above the wrist It runs downwards and backwards under cover of flexor carpi ulnaris and becomes cutaneous in the distal fourth of the forearm. It then winds around the medial side of the wrist to reach the dorsum of hand. After giving out cutaneous branches to the wrist and back of hand, it terminates in three (sometimes two) ***dorsal digital branches***. The most medial digital branch runs along the medial border of dorsum of hand and supplies the medial side of the little finger till the root of nail. The next branch divides into two branches at the cleft between the little and ring fingers which then supply their adjacent sides. The third branch supplies the adjacent sides of the ring and middle fingers. The area of skin supplied by the dorsal digital branches extends only up to the middle phalanx; the skin over the distal phalanx (and over part of the middle phalanx) is supplied by the palmar branches.

Branches in the Hand

Passing under the superficial part of the flexor retinaculum along with the ulnar artery, the ulnar nerve gives out a small muscular branch and two terminal branches.

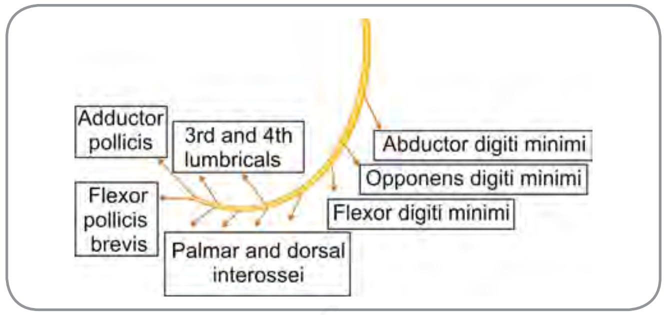


Fig. 17.37: Distribution of the deep terminal branch of the ulnar nerve

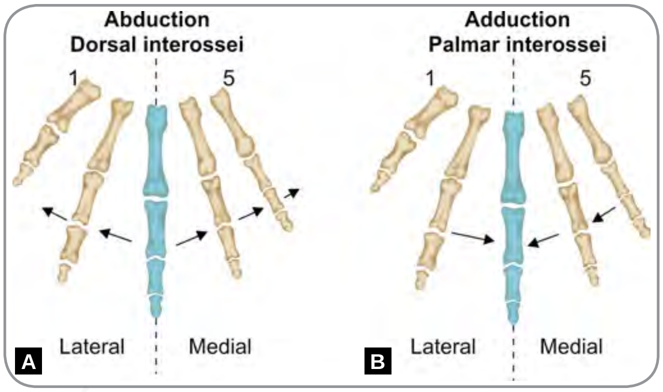
Interossei of the Hand

The palmar and dorsal interossei of the hand can be cal ed the adductors and abductors of fingers. Simple arithmetic calculation will give a comprehensive picture of their actions. Each of the digits can be moved away from or moved towards the axial line of the hand (that passes through the middle finger). If one muscle is required for each of these movements, then ten muscles (5 digits x 2 movements each) are needed to perform all these actions. With regard to the thumb, adduction and abduction are taken care by the adductor and abductores pollicis (two abductor muscles infact); with regard to the little finger, abduction is taken care by the abductor digiti minimi. Of the ten movements, three movements are already taken care of. For the remaining seven movements, seven interossei (4 dorsal + palmar) act

Four dorsal interossei fill the four intermetacarpal spaces. Each dorsal interosseous muscle arises by double heads from the adjacent sides of the corresponding metacarpal bones (first from 1 and 2, second from 2 and 3, third from 3 and 4, fourth from 4 and 5). These muscles abduct [remember the mnemonic—PAD (palmar adduct) and DAB (dorsal abduct)]. Of the five digits, thumb and little finger already have their abductors. Only the remaining three digits require abductors. The middle finger is special because it requires two abductors. The middle finger is on the axial line; so, its movement to the radial side is radial abduction and movement to the ulnar side is ulnar abduction. Therefore, two dorsal interossei, which are on either side of the middle finger insert into the medial and lateral sides of the finger. Of the remaining two dorsal interossei, the one on radial side of the forefinger (occupying the first intermetacarpal space) inserts to the radial side of the forefinger; that which is on the ulnar side of the ring finger (occupying the fourth intermetacarpal space) inserts to the ulnar side of the ring finger. (The given illustration will provide the clue to the lines of movement.)

Three palmar interossei are present. Adduction of fingers is a natural and pro-gravity movement; so, the palmar interossei are thinner than their dorsal counterparts and arise by single heads only. These muscles adduct. Of the five digits, the thumb already has its adductor. The middle finger cannot be adducted since it lies on the axial line itself. Only the second, fourth and fifth digits require interosseous adductors. Each palmar interosseous muscle arises from the metacarpal of the digit on which it acts. At their insertions, the first palmar interosseous attaches to the ulnar side of the forefinger, the second to the radial side of the ring finger and the third to the radial side of the little finger (Figs. 17.38A and B).

contd...



Figs 17.38A and B: Scheme to illustrate abduction and adduction of the digits of the hand

contd...

All the insertions of the interossei are partly into the bases of the proximal phalanges and partly into the dorsal digital expansions. All interossei are supplied by the ulnar nerve with the first dorsal being supplied by the median nerve occasionally.

Muscular Branches

A small muscular branch is given out as the ulnar nerve enters the palm and supplies the palmaris brevis muscle.

The other muscular branches are given as branches of the deep terminal branch.

Terminal Branches

There are two terminal branches, the superficial and deep branches.

1. The ***superficial terminal branch*** of the ulnar nerve arises after the nerve enters the hand. It divides into two ***palmar digital branches***, one for the medial side of the little finger and the other for the contiguous sides of the little and ring fingers. These nerves supply the skin on the palmar surfaces of the digits. They also supply the nail bed and the skin over the dorsal surface of the distal phalanx and part of the middle phalanx of the digit concerned.
2. The ***deep terminal branch*** of the ulnar nerve arises in the hand and is mainly muscular. The proximal part of the nerve supplies the ***hypothenar muscles***, namely the abductor digiti minimi, the opponens digiti minimi and the flexor digiti minimi. After supplying the hypothenar muscles the nerve runs transversely across the palm deep to the flexor tendons. Here it supplies the following—(a) all the palmar and dorsal ***interossei*** of the hand; (b) the third and fourth ***lumbrical muscles***; (c) the adductor pollicis and frequently the flexor pollicis brevis. Small twigs to the joints of the medial side of the hand and the vessels of the area are also given out.

Ulnar nerve (in the forearm): Point A is marked on the lower aspect of the medial epicondyle of humerus. Point B is marked immediately lateral to the pisiform bone. The two points are joined by a line that follows the tendon of flexor carpi ulnaris in its lower half. This line indicates the ulnar nerve in the forearm.

Added Information

The ulnar nerve enters the hand by passing superficial to the flexor retinaculum, lying in a g oove on the lateral aspect of the pisiform bone. A thin band of fibrous tissue stretches from the superficial aspect of the flexor retinaculum to the ventral lip of the pisiform groove. The canal thus formed is called ***the ulnar canal or the Guyon canal***.

Clinical Correlation

Effects of Injury to the ulnar nerve: The ulnar nerve is most often injured as it lies behind the medial epicondyle of the humerus. The nerve may also be injured in the cubital tunnel formed by the tendinous arch connecting the humeral and ulnar heads of the flexor carpi ulnaris (cubital tunnel syndrome), in the wrist when it passes through the Guyon canal (ulnar canal syndrome) and in the hand.

Muscles supplied by the ulnar nerve may be paralysed depending upon the level of injury.

Muscles paralysed	Effects thereof
Flexor carpi ulnaris	Flexion and adduction at the wrist are weak. The wrist is abducted by the flexor carpi radialis (median nerve) when flexion is attempted.
Flexor digitorum profundus	Only part of the muscle is supplied by the ulnar nerve—because of paralysis of the medial part of the muscle, the terminal phalanges of the ring and little finge s cannot be flexed.
Hypothenar muscles	Movements of the little finger are affected. There is wasting of the hypothenar eminence.
Interossei	Abduction and adduction of the fingers is weak. Flexion of the metacarpophalangeal joints and extension of interphalangeal joints of the fingers is not possible; the metacarpophalangeal joints remain extended and the interphalangeal joints remain flexed resulting in a claw hand

Sensations are impaired in the area of supply.

- Ulnar nerve paralysis gives rise to a partial claw hand—the medial two digits being the most affected. Extension of the interphalangeal joints is not possible. Interosseous muscles supplied by the ulnar nerve are paralysed. Extension of the metacarpophalangeal joints occurs due to unopposed

contd...

Clinical Correlation *contd...*

action of the extensors and flexion of the interphalangeal joints due to the unopposed action of the flexor digitorum profundus.

- Complete claw hand is seen in combined lesions of the ulnar and median nerves.
- ***Handle bar neuropathy:*** This is a condition that is likely to occur in individuals who ride bicycles or motor bikes for a long time. Their wrists are extended (or even hyperextended); as they apply pressure on the hand grips, hooks of the r hamates are pressed upon leading to compression of their ulnar nerves. Paralysis of the intrinsic muscles of hand associated with sensory loss on the medial aspect of the hand is seen.
- The median nerve supplies lateral three and half fingers on their palmar surfaces and the ulnar nerve the remaining one and half fingers. On the dorsal surface, (though it is customary to describe lateral three and half and medial one and half distribution to radial and ulnar nerves respectively), medial two and half finge s are supplied by the ulnar nerve and the remaining fingers by the radial nerve. The median nerve, of course, supplies the dorsal surface of the distal phalanx of the thumb and the distal two phalanges of the index, middle and half ring fingers. The ulnar distribution of one and half on the palmar surface and two and half on the dorsal surface is based on clinical observations.
- ***Digital nerve blocks:*** When it is necessary to perform surgical procedures in the fingers, the digital nerves can be blocked by injecting anaesthetic agents. There are four digital nerves in any finger: two palmar and two dorsa . The anaesthetic is injected by inserting the needle from the dorsal aspect on either side of the base of the finger

Radial Nerve

The radial nerve is the main continuation of the posterior cord of the brachial plexus. Lying behind the axillary artery in the axilla and behind the brachial artery on the medial aspect of humerus in the arm, the nerve reaches the spiral groove along with the profunda brachii artery. Winding around the humerus and piercing the lateral intermuscular septum, it comes to the anterior compartment in the distal third of the arm. It descends between the brachialis (medially) and the brachioradialis and the extensor carpi radialis longus (laterally). It ends in front of the lateral epicondyle of the humerus by dividing into superficial and deep terminal branches.

Branches of Radial Nerve

The branches of the radial nerve in the arm are the posterior cutaneous nerve of arm, lower lateral cutaneous nerve of arm, posterior cutaneous nerve of forearm and muscular branches to triceps, anconeus, brachioradialis and extensor carpi radialis longus. Extensor carpi radialis brevis and brachialis may also receive branches from the radial nerve.

The posterior cutaneous nerve of forearm, though given out in the arm, is a nerve of the forearm. It is given out when the radial nerve is in the posterior compartment of arm; it pierces the deep fascia and descends into the back of forearm in the superficial fascia. It supplies the skin and fascia of the middle portion of the back of forearm, till the wrist.

Terminal Branches (Fig. 17.39)

The ***superficial terminal branch*** (an apparent continuation of the main trunk and so, was formerly called the ***radial nerve***) runs downwards in front of the lateral

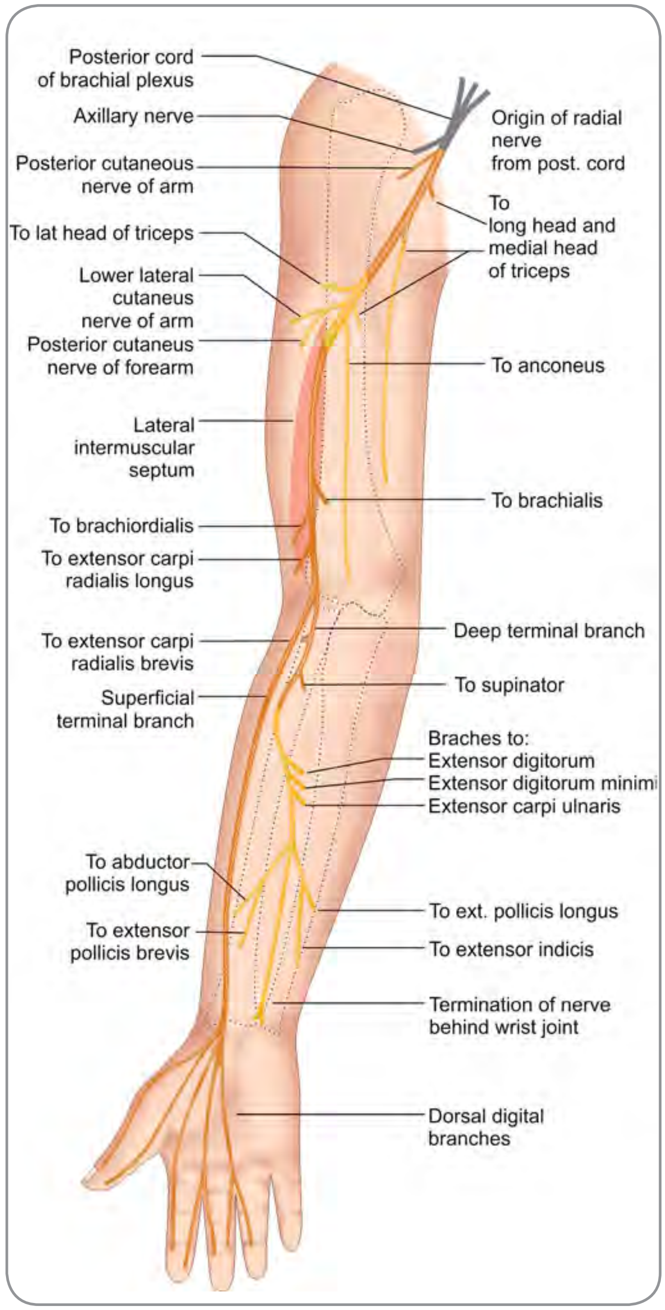


Fig. 17.39: Scheme to show the course and distribution of the radial nerve and its terminal branches, as seen from the front—the pa ts of the nerve (and b anches) shown in brown line are located on the dorsal aspect of the limb

part of the forearm, overlapped by the brachioradialis. Lying successively on the supinator, pronator teres, flexor digitorum superficialis and flexor pollicis longus, the nerve is accompanied by the radial artery on its medial aspect. In the lower-third of the forearm, the nerve passes backwards (leaving the company of the artery) around the lateral side of the radius to reach the dorsum of the hand; after giving small twigs to the dorsum of wrist and the lateral side of the dorsum of hand, it ends by dividing into four or five ***digital branches***.

- The first of these (most lateral) supplies the skin of the lateral side of the thumb.
- The second branch supplies the medial side of the thumb.
- The third branch supplies the lateral side of the index finger.
- The fourth branch supplies the contiguous sides of the index and middle fingers.
- The fifth (when present) supplies the contiguous sides of the middle and ring fingers.

The dorsal digital branches do not extend to the distal ends of the digits. As stated above, the skin over the distal phalanges and the whole or part of the middle phalanges is supplied by palmar digital branches of the median nerve.

The ***deep terminal branch*** is also called the ***posterior interosseous nerve***. It is the only nerve found inside the posterior compartment. Soon after its origin in the cubital fossa, it disappears from view by entering the substance of the supinator muscle; within the muscle, it runs downwards winding around the lateral side of the radius. It appears in the back of the forearm through the lower part of the supinator muscle and gives several branches which supply the muscles of this region. The nerve first lies between the superficial and deep muscles of the back of the forearm, but its lowest part lies behind the interosseous membrane (where it is accompanied by the anterior interosseous artery). In the upper part of its course in the posterior compartment, the nerve is accompanied by the posterior interosseous artery. Reaching the dorsal aspect of the wrist, the posterior interosseous nerve and the anterior interosseous artery occupy the fourth compartment of the extensor retinaculum. At this point the nerve terminates in a pseudoganglion.

Before entering the supinator, the nerve gives branches to the extensor carpi radialis brevis; once within the substance of the supinator, the nerve supplies that muscle; while passing through the posterior compartment of forearm, it supplies short muscular branches to extensor digitorum, extensor digiti minimi and extensor carpi ulnaris; it then gives long muscular branches to extensor indicis, extensor pollicis longus, abductor pollicis longus and extensor pollicis brevis. Branches from the pseudoganglion supply the wrist joint and the intercarpal joints.

Radial nerve (in the forearm): Point A is marked on the anterior aspect of the forearm at the level of the lateral epicondyle about 1.5 cm lateral to the bicipital tendon. Point B is marked at the junction of the middle and the lower thirds of the lateral border of the forearm. Point C is marked in the anatomical snuff box immediately lateral to the radial artery. Points A and B are joined by a line that is curved towards the lateral aspect Points B and C are joined by a line that runs inferiorly. The whole stretch indicates the radial nerve in the forearm.

Clinical Correlation

- ***Effects of injury to the radial nerve:*** The effects of injury to the radial nerve depend on the level of injury. All muscles supplied by it are affected in injuries to it in the axilla. It is, however, most frequently injured as it lies in the radial groove; in this case the triceps is spared as the nerves to it arise higher up.

Muscle(s) paralysed	Effects thereof
Triceps	The elbow cannot be extended.
Extensors of wrist and digits	The wrist and proximal phalanges cannot be extended. The wrist remains flexed—this condition is called ***wrist drop.***
Supinator	Supination is not possible with the forearm extended. However, if the forearm is flexed the biceps brachii produces this movement.

Although the radial nerve supplies an extensive area of skin much of the area is also supplied by other nerves. Because of this fact, sensations are lost only in a small area of skin on the lateral part of the dorsum of the hand.

- ***PIN syndrome:*** When the posterior interosseous nerve passes through the substance of the supinator, it may be compressed by a rare musculotendinous arch present in the proximal part of the muscle. This condition is called the posterior interosseous nerve syndrome. The first muscle to be affected is extensor carpi ulnaris. Extension of wrist causes radial deviation due to overactivity of the extensor carpi radialis muscles. Subsequently, weakness of extension and abduction of thumb occurs (leading to thumb drop) followed by weakness of extension of fingers (fingers drop).

Compartments and Spaces of the Hand

To understand the compartments and spaces of the hand, it is necessary to recapitulate the details about the palmar aponeurosis and its fascial extensions. The ***palmar aponeurosis*** is a triangular sheet of dense fascia that covers the central part of the palm. The lateral palmar septum passes from the lateral edge of the aponeurosis to the first metacarpal bone. The medial edge of the palmar aponeurosis is connected to the fifth metacarpal bone by the medial palmar septum. These septa divide the palm into three main compartments, namely—the hypothenar (or medial), thenar (or lateral) and intermediate compartments.

Fascial Compartments: The ***hypothenar***, ***thenar*** and ***intermediate*** compartments are the fascial compartments of the hand To these may be added another compartment

called the ***adductor*** compartment. The anterior surfaces of the metacarpal bones, the intervening interossei muscles and the adductor pollicis muscle that overlies the lateral metacarpals and interossei are covered by a layer of deep fascia. The medial and the lateral palmar septa merge with this layer at their deep attachments, i.e. the anterior aspects of the fifth and first metacarpal bones respectively. With a firm layer of fascia over it, the adductor pollicis is shut off from the intermediate compartment. However, some space exists between the muscle and the underlying metacarpal bones and interossei. This space and the adductor pollicis together form the constituents of the adductor compartment. The hypothenar compartment has the hypothenar muscles and the thenar compartment has the thenar muscles.

The ***intermediate compartment*** lying deep to the palmar aponeurosis, is bounded medially and laterally by the corresponding palmar septa. It contains the tendons of the flexor digitorum superficialis, flexor digitorum profundus and flexor pollicis longus, the lumbrical muscles, the superficial palmar arch and its digital branches, the deep palmar arch and the digital branches of the median and ulnar nerves. The intermediate compartment is further subdivided into two parts by an ***intermediate palmar septum*** (also called the ***oblique palmar septum;*** clinicians call it the ***lateral fibrous septum***). This septum passes from the deep surface of the lateral part of the palmar aponeurosis to the front of the third metacarpal bone. The lateral part of the intermediate compartment that lies between the lateral and the intermediate palmar septa is the thenar space (space and not compartment; there is another thenar compartment). The medial part of the intermediate compartment that lies between the intermediate and the medial palmar septa is the midpalmar space.

Fascial Spaces

The fascial spaces of hand are variedly known as the fascial spaces of palm, the palmar spaces and the spaces of hand. These are not well marked fascial compartments. Under normal circumstances the spaces cannot be made out. However, potential spaces exist between the various structures; if there is a necessity, these spaces come into view. In certain diseased conditions, fluid or pus is formed; these collect in certain specified areas, indicating such space was potentially available before the fluid or pus accumulation and has come into view only after the accumulation. The potential specified areas are called the ***fascial spaces***.

- Thenar space, midpalmar space, web spaces and pulp spaces are the fascial spaces on the palmar aspect of the hand
- Space of parona is a fascial space present in the lower part of forearm.
- Dorsal subcutaneous and dorsal subaponeurotic spaces are fascial spaces found in the dorsum of hand.

Thenar and midpalmar spaces: Both appear more or less triangular; the base of each space lies distally and the apex is directed proximally. The fascia covering the deep palmar muscles forms the posterior limit of the spaces.

- ***Thenar space:*** It is the potential space in the lateral part of the intermediate compartment. Its boundaries are:
  - ***Medially:*** Intermediate palmar septum;
  - ***Laterally:*** Lateral palmar septum;
  - ***Anteriorly:*** Lateral part of palmar aponeurosis and flexor tendons to index finger;
  - ***Posteriorly:*** Adductor pollicis (transverse head) and the fascia over it

The tendon of the flexor pollicis longus lies in front of the lateral part of this space and is sometimes described as part of the lateral wall.

- ***Midpalmar space: It is the potential space in the medial part of the intermediate compartment. Its boundaries are:***

  Medially: Medial palmar septum;

  Laterally: Intermediate palmar septum;

  Anteriorly: Medial part of palmar aponeurosis and flexor tendons to medial three fingers;

  Posteriorly: Fascia covering the medial three metacarpal bones and intervening interosseous muscles.
- ***Proximal and distal extent of the spaces:*** Proximally, the midpalmar and thenar spaces extend up to the distal margin of the flexor retinaculum. Distally, the thenar space extends up to the proximal transverse crease of the palm and the midpalmar space extends up to the distal transverse crease. Incisions are made through these creases to drain the spaces At the distal aspects, the thenar can be seen to be continuous with the first lumbrical space and the midpalmar space with the lumbrical spaces of the medial fingers. These extensions obscure the triangular shape of the thenar and midpalmar spaces.
- ***Communications of the spaces:*** The spaces are normally closed at the proximal end. However, the midpalmar space may communicate with the forearm space (space of Parona) through the carpal tunnel. The two spaces of the palm quite frequently communicate with each other and infection can pass from one to the other.
- ***Contents of the thenar and midpalmar spaces:*** The spaces are normally filled mainly with loose connective tissue. When infected, they can be distended with pus. These spaces are closely related to the lumbrical muscles. The thenar space contains the first lumbrical muscle while the midpalmar space contains the second, third and fourth lumbrical muscles. The tendon of each lumbrical muscle is surrounded by a ***lumbrical canal***. When traced distally, the thenar space becomes continuous with the lumbrical canal which surrounds the tendon of the first lumbrical muscle. The midpalmar space becomes continuous with the lumbrical canals of the second, third and fourth lumbrical muscles.

- ***Variation in spaces:*** Occasionally, the intermediate palmar septum passes through the interval between the flexor tendons for the middle and ring fingers (instead of passing between the tendons of the index and middle fingers). In that case, the second lumbrical muscle and its lumbrical canal are related to the thenar space and not to the midpalmar space.
- ***Relationship to the ulnar and radial bursae:*** The long flexor tendons to the medial four fingers form the anterior limits of the thenar and midpalmar spaces. Therefore, the ulnar bursa (common synovial sheath) is intimately related to both the spaces. The radial bursa (synovial sheath of the flexor pollicis longus tendon) is on the lateral aspect of the thenar space and still closely related.

Clinical Correlation

Tenosynovitis of the tendons can cause secondary abscesses in the fascial spaces. The tendon sheath of the little finger is continuous with the ulnar bursa. Tenosynovitis of the little finger can infect the ulnar bursa. Similarly, tenosynovitis of the thumb can infect the radial bursa because of the continuity of the tendon sheaths. Inflamed ulnar bursa can burst into the midpalmar space and inflamed radial bursa can burst into the thenar space resulting in abscesses in these spaces.

Web Spaces

In the gaps between the roots of fingers, folds of skin are seen. Subcutaneous spaces within these folds are the web spaces. Thus, there are four web spaces between the five fingers. Each web space extends from the free margin of the skin fold to the level of the metacarpophalangeal joints. Subcutaneous fat, superficial transverse metacarpal ligament, tendons of corresponding lumbricals and interosseous muscles and digital vessels and nerves are the contents of the web spaces.

Pulp Spaces of Fingers

Pulp space is a subcutaneous space between the skin on the palmar aspect of the terminal phalanx and the underlying bone. The boundaries of a pulp space are:

Proximally: Fusion of fibrous flexor sheath of the digit to the periosteum of the terminal phalanx posteriorly and to the skin at the distal digital crease anteriorly;

Distally: Tip of the digit;

At the Sides: Fusion of the deep fascia to the periosteum on the sides of the terminal phalanx.

The pulp space contains a number of septa which pass from the skin to the periosteum. Each compartment is normally occupied by fat. The digital vessels and nerves are also present in the space. Before the digital artery enters the pulp space, it gives off an epiphyseal branch that supplies the basal portion of the terminal phalanx. The diaphyseal branches arise within the space and enter into the shaft portion of the bone.

Clinical Correlation

Infections in the region of the fingertips are commonly caused by pinpricks or cuts. Such infections cause much pain because the region of the tip of the finger is divided into a number of small compartments and distension of any compartment with pus presses on nerve endings there. Collection of pus in the pulp space leads to a condition called felon or whitlow. The diaphyseal branches may also be compressed and blocked by thrombosis. In such a case, the distal portion of the terminal phalanx suffers avascular necrosis Drainage of pus should be done through the point of maximum tenderness; drainage prevents complications.

Space of Parona

This is a potential space found in the distal forearm; it is found between the long flexor tendons and the pronator quadratus muscle. The midpalmar space sometimes may communicate with this space under cover of the flexor retinaculum.

As already seen, the ulnar and the radial bursa extend about 2 cm proximal to the flexor retinaculum. An inflamed ulnar or radial bursa may burst into the space of Parona. The space is drained through incisions along the lateral and medial borders of the lower part of the forearm.

Other Spaces in the Hand

There are two spaces on the dorsum of the hand which are occasionally sites of infection. The ***subcutaneous space*** lies immediately under the skin and superficial to the fascia over the extensor tendons. The ***subaponeurotic space*** lies deep to the extensor tendons. Infections from the digits and palm can travel to these spaces through lymphatics.

Development

The upper limb buds are opposite the lower cervical and upper thoracic segments. The dorsolateral cells of the concerned somites migrate into the buds and form a muscle tissue mass. With further elongation of the limb buds, the muscle mass splits into two: the ventral flexor mass and the dorsal extensor mass. However, each of these masses splits and fuses again and again such that a single muscle of the limb may be formed from components of more than one original muscle piece.

The ventral primary rami of the concerned spinal nerves also enter the buds. Each of these rami has a ventral and a dorsal division. Subsequently, the ventral divisions of all the rami join together and the doral divisions also do so. The radial nerve is derived from the dorsal divisions and so supplies the dorsal extensor musculature. The median and the ulnar nerves are derived from the ventral divisions and so supply the ventral flexor musculature.

The contact between the nerves which penetrate into the limb buds and the mesenchyme of the buds is established quite early in development. This contact acts as a stimulus for complete functional differentiation of the muscles.

Multiple Choice Questions

1. The ulnar head of Pronator teres separates the ulnar artery from:
   a. Median nerve
   b. Radial nerve
   c. Ulnar nerve
   d. Axillary nerve
2. Flexion of fingers is powerful during wrist extension because:
   a. The operating distance of long flexors is decreased
   b. The operating distance of long flexors is increased
   c The wrist flexors counteract the finger extensors
   d. The wrist flexors add to finger flexion
3 What is untrue about opposition?
   a. It is a complex movement that involves both the carpometacarpal and the metacarpophalangeal joints of the thumb
   b. Cupping of the palm is a prerequisite for better opposition
   c Opponens pollicis contributes only to a part of the entire range of opposition
   d. Adductor pollicis has no role to play in the movement
4. The ulnar artery:
   a. Is the smaller terminal branch of brachial artery
   b. Runs most of its course at the back of forearm
   c. Is accompanied by a single ulnar vein
   d. Is overlapped by the Flexor carpi ulnaris in the middle of its course
5. Carpal rete is the other name for:
   a. Dorsal metacarpal network
   b. Princeps pollicis artery
   c. First palmar metacarpal artery
   d. Palmar carpal arch

ANSWERS

1. a **2.** b **3.** d **4.** d **5.** a

Clinical Problem-solving

Case Study 1: A 36-year-old woman was on a holiday tour to a hill station. As she was walking along a road, she noticed her hands were pale. Few minutes later, her hands became dark and swollen. She sat down in fear.

- What is your diagnosis about her condition?
- What do you expect to happen next?
- What is the cause of this problem?

Case Study 2: A 24-year-old man was on a mission cycle trip. When he returned after a week, he complained of sensory loss in both his hands, but more on the right side.

- What is the condition that the man is suffering from?
- What is the mechanism that causes this condition?
- What other symptoms (and signs) do you expect?

(For solutions see Appendix).

Chapter 18

Joints of Upper Limb

Frequently Asked Questions

- Discuss the shoulder joint with relation to its fibrous capsule, ligaments, synovial membrane, relations and movements.
- Discuss the elbow joint with relation to its fibrous capsule, ligaments, synovial membrane, relations and movements
- Discuss the radiocarpal joint with relation to its fibrous capsule ligaments, synovial membrane, relations and movements.
- Discuss the midcarpal joint with relation to its fibrous capsule, ligaments, synovial membrane, relations and movements.
- Discuss the carpometacarpal joint of the thumb with relation to its fibrous capsule, ligaments, synovial membrane, relations and movements.
- Write notes on (a) Sternoclavicular joint, (b) Acromioclavicular joint, (c) Glenohumeral ligaments, (d) Rotator cuff, (e) Coracoacromial arch, (f) Ulnar collateral ligament of elbow, (g) Glenoidal labrum, (h) Scapula and its influence on the shoulder joint, (i) Scapulohumeral rhythm, (j) Carrying angle, (k) Annular ligament, (l) Factors contributing to the stability of the shoulder, (m) Bursae around the shoulder, (n) Abduction and elevation of arm, (o) Movements of thumb, (p) Opposition movement, (q) Abduction–adduction of fingers, (r) Writing position, (s) Interosseous membrane of upper limb.

JOINTS OF UPPER LIMB

Joints of upper limb constitute the joints of the shoulder girdle and the joints of the limb proper. The human body, during the process of evolution, had undergone modifications to adapt to a skilled style of life. With the upper (or the fore) limbs becoming 'free' from the burden of locomotion and weight transmission, their functionality has been focussed on their ability to grip grasp and execute skilled movements. The joints of the upper limb have, therefore, been provided with more mobility than stability.

The shoulder is the most mobile of all joints of the human body. The clavicle, takes upon itself the responsibility of keeping the upper limb clear of the trunk to enable smooth functioning of the limb without any impingement or obstruction. The forearm has a special set of movements, namely pronation and supination, which enhances the skill of the upper limb. The hand (along with the fingers) is anatomically designed for intricate movements and coordination.

JOINTS OF SHOULDER GIRDLE

Clavicle and ***scapula*** constitute the shoulder girdle. The two bones articulate with each other through the acromioclavicular joint. The girdle itself articulates with the axial skeleton through the sternoclavicular joint. Thus the clavicle directly articulates with the axial skeleton but the scapula does not.

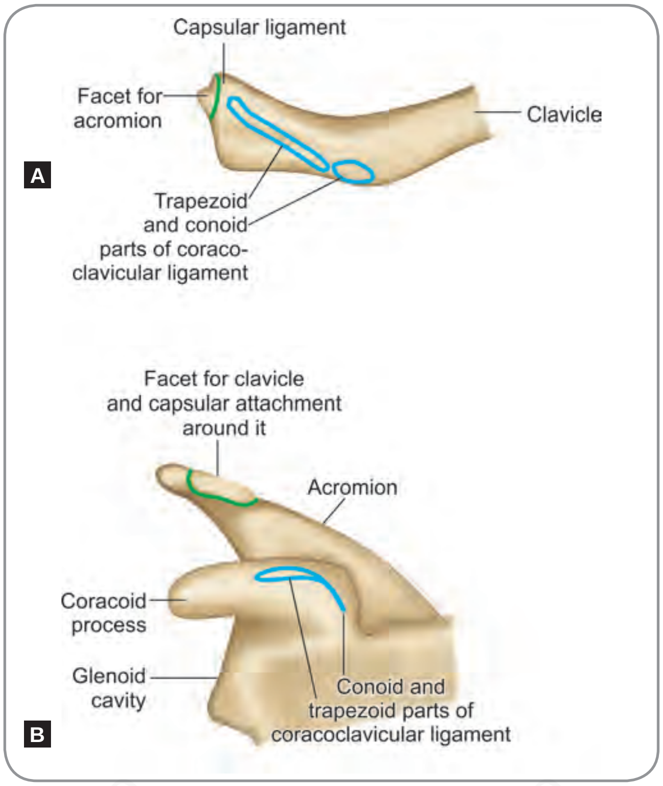
JOINT CONNECTING SCAPULA AND CLAVICLE

Acromioclavicular Joint

It is a synovial joint of the plane variety, between the lateral end of clavicle and the medial aspect of acromion.

Articular surfaces: These are two small oval facets, one on the lateral end of clavicle and the other on the medial margin of acromion. Both facets are covered with articular cartilage and both slope downwards and medially. The slope causes the clavicle to override the acromion.

Articular capsule and ligaments: A weak fibrous capsule surrounds the joint. The cavity of the joint is often partially subdivided by a wedge shaped articular disc. The capsule is thickened on its upper part and is reinforced by the acromioclavicular ligament and fibres of trapezius (F gs 18.1A and B).



Figs 18.1A and B: Facets for acromioclavicular joint and attachments of coracoclavicular ligament **A.** Lateral end of clavicle (seen from below) **B.** Upper part of scapula (viewed from the front)

However, the structure of importance is the ***coracoclavicular ligament*** (Fig. 18.2). It is an extracapsular accessory ligament of the joint and extends from the superior surface of coracoid to the inferior surface of clavicle. It also serves as the main bond of union between the scapula and clavicle. Though not usually so described, it is really a syndesmosis connecting the clavicle to the coracoid process. The ligament consists of two parts, so named because of their shape: (1) trapezoid and (2) conoid.

1. The ***trapezoid part*** is attached, below, to the superior surface of the coracoid process; and, above, to the trapezoid line on the inferior surface of the lateral part of the clavicle; the attachments are slightly askew so that this part lies more or less horizontal.
2. The ***conoid part*** is attached, below, to the root of the coracoid process just lateral to the scapular notch and above, to the inferior surface of the clavicle on the conoid tubercle; the coracoid attachment is the apex and the clavicular attachment the base of the cone. The two parts are continuous posteriorly but are separated anteriorly by an interval that is usually occupied by a bursa.

The joint is supplied by branches of adjacent arteries and by twigs of lateral pectoral, suprascapular and axillary nerves.

Movements: Movements at this joint accompany those at the sternoclavicular joint. These movements are necessary for allowing various movements of the scapula associated with movements of the arm at the shoulder joint. Vertical movement of the scapula on the chest wall, gliding forward and backward of the scapula on the clavicle and free elevation of the free upper limb are possible by movements occurring at the acromioclavicular joint. The two parts of the coracoclavicular ligament play an important role in stabilising the clavicle in particular and the shoulder region in general. The conoid part prevents backward movement of the lateral part of the clavicle without any similar movement of the scapula; the trapezoid part prevents any such forward movement. Both of them together prevent the acromion being carried medially below the clavicle when blows or forces fall on the lateral aspect of shoulder.

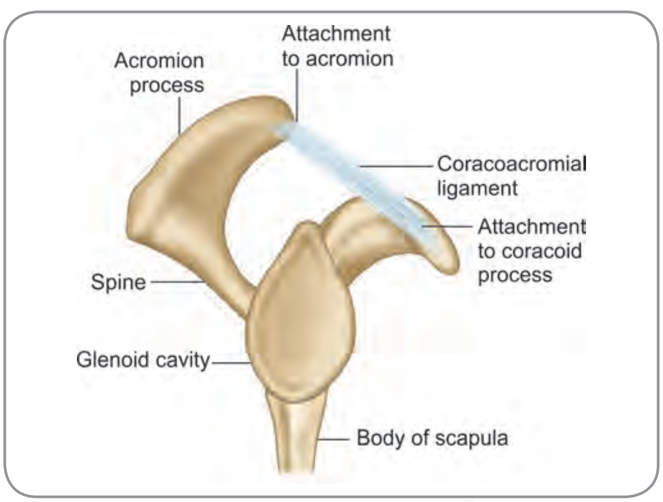


Fig. 18.2: Upper part of scapula–lateral view to show attachments of coracoacromial ligament

Dissection

Dissect the acromioclavicular and sternoclavicular joints only on one side. To study the acromioclavicular joint, clean the superior and inferior ligaments first. Open the joint, clean and define the coracoacromial and coracoclavicular ligaments. To study the sternoclavicular joint, detach the sterna head of the sternocleidomastoid first. Clean and define the sternoclavicular and interclavicular ligaments. Detach or cut the subclavius if necessary. Identify the costoclavicular ligament. Then open the joint to see the articular capsule.

It is important to study the shoulder joint. Identify the subscapularis muscle and tendon. See for the subscapular bursa and also note if it communicates with the joint cavity. Clean the coracoclavicular ligament. Identify the short and long heads of biceps, coracobrachialis and the joint capsule. Detach both the short head and coracobrachialis from their origins. Look for the coracohumeral ligament and define it. Turning the cadaver around, make a vertical incision in the posterior part of the joint capsule. If the arm is now rotated medially, the glenohumeral l gaments can be seen clearly. Slowly working

contd...

Dissection *contd...*

through the anterior part of the capsule, disarticulate the head of humerus. As you proceed to work, study the long head of biceps and its tendon. Cut the tendon to ensure separation of humerus. Once the humerus is separated off, study the glenoidal labrum and the other relations of the joint.

Clinical Correlation

Dislocation of acromioclavicular joint can occur, wherein the transmission of weight to the axial skeleton is hindered. Severe blows to the curve of the shoulder may tear the coracoclavicular ligament and push the acromion beneath the clavicle. This condition is called ***shoulder separation***.

JOINT CONNECTING THE GIRDLE AND STERNUM

Sternoclavicular Joint

It is a compound synovial joint of the saddle variety between the medial end of clavicle, the superolateral angle of sternum and the medial end of the first costal cartilage

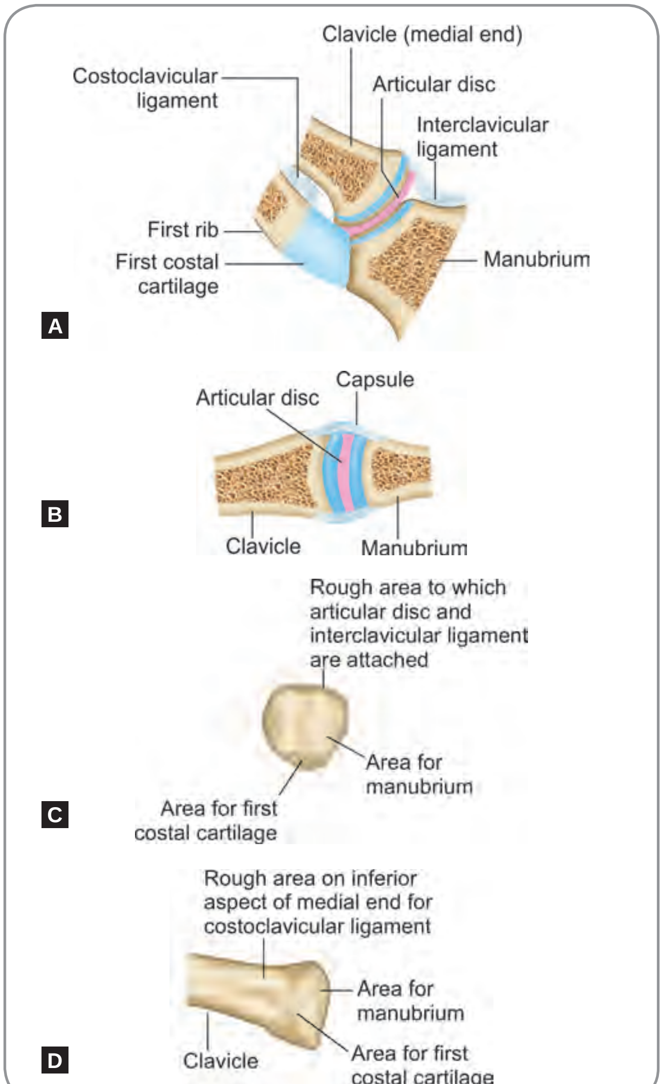
Articular surfaces: There are three elements taking part in this joint, namely—(1) the medial end of the clavicle, (2) the clavicular notch of the manubrium sterni and (3) the upper surface of the first costal cartilage. The articular surfaces are concavo-convex; that on the clavicle being convex vertically and concave horizontally. The articular surface of the clavicle is also slightly larger so that the medial end of clavicle projects above the manubrium sterni. This surface is covered with fibrocartilage (not hyaline cartilage, as the clavicle is a membrane bone) (Fig. 18.3A).

Articular capsule and ligaments: The fibrous capsule is attached laterally around the clavicular articular surface and medially to the margins of the articular areas on the sternum and on the first costal cartilage, thus surrounding the joint completely. It is thickened in front and behind and is weak inferiorly (Fig. 18.3B).

A fibrocartilaginous ***articular disc*** divides the joint cavity; it is fused to the internal aspect of the capsule both in front and behind; it is also attached, above to the clavicle and below to the first costal cartilage. Due to such anchorage, the disc also acts as a strengthening ligament, in addition to providing cushioning effect to the joint; it prevents the medial end of clavicle being pushed upwards on the sloping sternochondral articular facet (Fig. 18.3C)

The articular disc divides the joint cavity into two separate synovial cavities; rarely, the two may communicate with each other due to a perforation in the thinner central part of the disc.

The thickened bands of the capsule in front and behind are called the ***anterior*** and ***posterior sternoclavicular ligaments*** and form reinforcements to the capsule proper. Both these ligaments pass downwards and medially from the clavicle to the sternum; the anterior ligament is stronger than the posterior. The ***interclavicular ligament*** passes between the sternal ends of the right and left clavicles, some of its fibres being attached to the upper border of the manubrium sterni; it is actually a continuation of the condensation of the joint capsule on the superior aspect. The ***costoclavicular ligament*** is an extracapsular ligament, situated a little away on the lateral side of the joint. It passes from the superior surface of the first costal cartilage to a rough tubercle on the inferior surface of the medial end of clavicle The anterior fibres pass upwards and laterally and the posterior fibres pass upwards and medially; this gives a cruciate arrangement to the fibres



Figs 18.3A to D: Sternoclavicular joint as seen in **A.** Coronal section **B.** Transverse section – the clavicular facet for the joint is shown **C.** From medial side and **D.** From below

of the ligament and the ligament itself is described to be consisting of two laminae, the anterior and the posterior. The ligament provides stability to the sternoclavicular joint and prevents elevation of clavicle (Fig. 18.3D).

The joint is supplied by branches of adjacent arteries and by twigs of medial supraclavicular nerve and nerve to subclavius.

Movements: Despite the concavo-convex nature of the articular surfaces, the sternoclavicular joint can be functionally regarded as a ball and socket joint. Movements of the clavicle is possible in very many directions. Maximal movement is possible in the coronal plane but both anteroposterior movements and rotational movements around the long axis also occur. Forward and backward movement of clavicle occurs in the medial compartment; elevation and depression of clavicle in the lateral compartment. The muscles responsible are as follows:

Forward movement	Serratus anterior
Backward movement	Trapezius and rhomboids
Elevation	Trapezius, sternocleidomastoid, levator scapulae and rhomboids
Depression	Pectoralis minor and subclavius

Clinical Correlation

Dislocations of the sternoclavicular joint are very rare; the costoclavicular ligament holds the medial end of clavicle in position. When there is any violent force, the bone usually fractures and the joint is spared.

In dislocations of the sternoclavicular joint the medial end of the clavicle is usually displaced forwards. Backward dislocation is much more serious as the bone may press on the trachea or one of the large vessels at the root of the neck.

MOVEMENTS AT SHOULDER GIRDLE

Though movements occur at the shoulder girdle, they invariably accompany movements at the shoulder joint. However, the girdle movements set stage for proper, effective and efficient shoulder movements. Movements at the shoulder girdle occur not only in the two constituent articulations of acromioclavicular and sternoclavicular joints but also in the functional scapulothoracic joint.

Forward movement of scapula along the thoracic wall causes the glenoid cavity to face forwards; backward movement causes the glenoid to face more laterally. Upward movement of scapula along with a rotation that causes the inferior angle to move superoanteriorly makes the glenoid cavity face upwards. Downward slide of scapula along with a rotation that causes the inferior angle to move medially makes the glenoid turn a little downwards.

The above mentioned movements of scapula (Table 18.1) occur predominantly (rather exclusively) at the scapulothoracic joint. However, the actual execution of these movements requires action at the other joints. Let us see this in detail. The scapula is joined to the trunk through the clavicle. The clavicle acts as a strut and by providing thrust at the acromioclavicular joint, keeps the scapular glenoid in such a way that the latter is free for varied movements. If the glenoid and the lateral angle of scapula have to maintain this freedom, they have to remain clear of the trunk and travel along the arc of a circle whose radius is the clavicle. On the contrary, the medial aspect of the scapular blade is held close to the thoracic wall and can only travel along the arc of a smaller circle and radius, namely, the thoracic wall curve. It is not possible for the scapular blade to travel through wider or larger arcs and circles. However, in order to retain the freedom of the upper limb, the lateral part of scapula has to travel wide. Therefore, it is clear that the portion of scapula in

Table 18.1: Movements of scapula

Movement	Muscles causing simple activity	Muscles causing rigorous activity
Simple elevation of scapula	Trapezius, levator scapulae, serratus anterior	Vigorous contraction of the same muscles when load/weight is supported/carried
Simple depression of scapula	No muscle – weight of the upper limb acts	Pectoralis minor acting on the girdle; pectoralis major and latissimus dorsi acting on the humerus
Elevation and rotation of scapula to make glenoid face upwards	Trapezius and serratus anterior	Trapezius and serratus anterior
Depression and rotation of scapula to make glenoid face downwards	Pectoralis minor, rhomboids, levator scapulae and trapezius	Added force by pectoralis major and latissimus dorsi
Protraction of scapula	Serratus anterior, pectoralis minor and levator scapulae	Helped by pectoralis major
Retraction of scapula	Trapezius and rhomboids	Helped by latissimus dorsi

relation with clavicle should be capable of modification. Such modification of the position of scapula occurs at the acromioclavicular joint, when the acromion glides on the clavicle. The movements of the free upper limb are thus protected and the all-too-important functions like grasp, grip, prehensility, push and forward thrust are maintained.

The sternal end of clavicle is almost anchored. But the acromial end is mobile and moves in various directions in association with the scapula. Forward, backward, upward and downward movements occur. In addition, rotational movements of the clavicle are also possible. It can be noticed that when the shoulder is elevated, the clavicle rotates around its own long axis in such a way that its anterior surface faces upwards. Impairment of clavicular rotation will cause restraint on the free movement of scapula and in turn, the shoulder.

Added Information

- The costoclavicular and coracoclavicular ligaments are considered degenerate medial and lateral ends of subclavius muscle. All three of them take the same direction.
- The interclavicular ligament connects the medial ends of the two clavicles across the jugular noth. It is a weak ligament and is a homologue of the wishing bone of the birds

JOINTS OF LIMB PROPER

SHOULDER JOINT

The shoulder joint (or the ***Glenohumeral joint***) is a specialised joint of the upper limb in which freedom of movement is well established at the expense of its stability. It is a multi axial synovial joint of the ball and socket variety and is the most mobile type of all the synovial joints of the body. Muscles and ligaments surrounding the joint attempt to compensate for the lack of stability. The joint is formed between the scapula (glenoid cavity of the scapula forming the socket) and the humerus (head of humerus forming the ball) and hence the name glenohumeral articulation.

Articular surfaces: The glenoid cavity (Fig. 18.4) is a shallow depression on the lateral angle of scapula and is directed laterally and forwards It is much smaller than the head of the humerus. The depth of the cavity is increased by a rim of fibrocartilage attached to its margin; this fibrocartilaginous structure is the glenoidal labrum. The depth is also increased by the articular cartilage lining it; the cartilage is thinnest at the centre and thickest at the periphery

The articular surface of the head of the humerus is rounded like a hemisphere and is directed medially, backwards and upwards. It is covered by a layer of hyaline

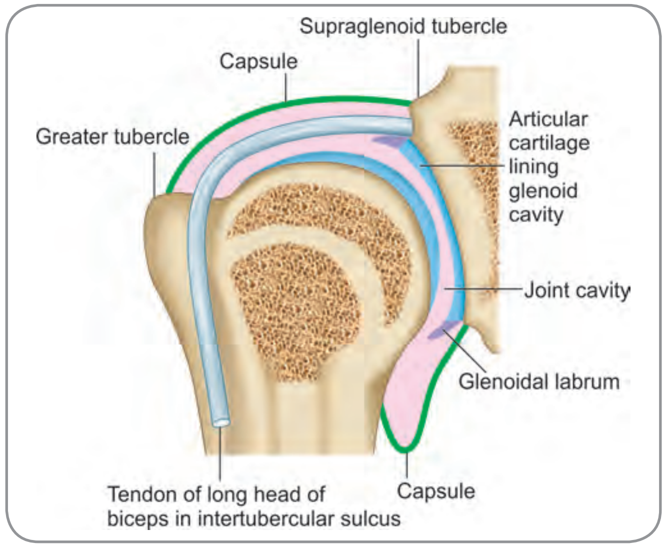
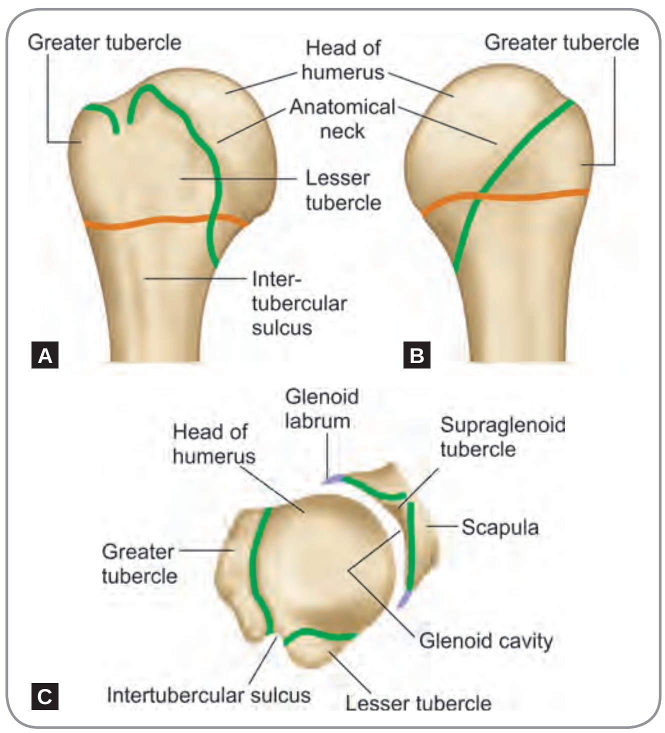


Fig. 18 4: Schematic coronal section through the shoulder joint

articular cartilage which is thickest at the centre and thinnest at the periphery, thus increasing the convexity.

Articular capsule: The fibrous capsule of the shoulder joint, though not a weak structure, is lax for the purpose of permitting free movements. Hence, its role in maintaining the strength of the joint is questionable. It is attached, on the scapular (which is also the proximal) aspect, to the margins of the glenoid cavity beyond the glenoidal labrum (Figs 18.5A to C), thus making the latter essentially an



Figs 18.5A to C: Upper end of humerus seen from: **A.** from front **B.** from behind **C.** from above; the attachment of the capsule is shown in green line; Note its relationship to the epiphyseal lines

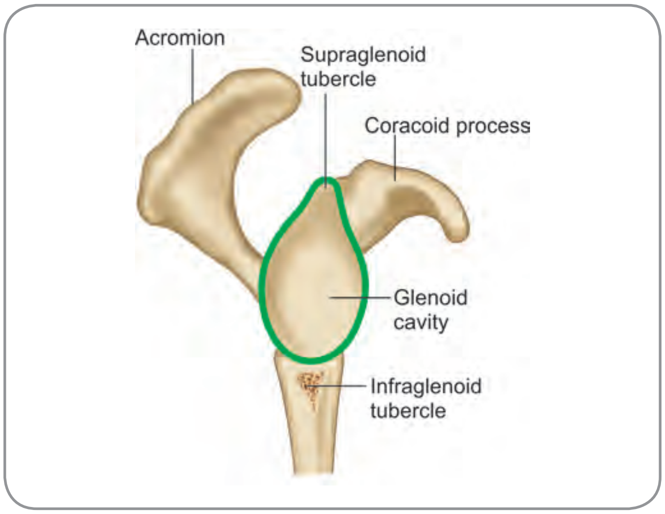


Fig. 18.6: Attachment of the capsule of the shoulder joint to the scapula (viewed from the lateral side) – Note the relationship of the capsule to the supraglenoid tubercle

intracapsular structure. Superiorly, the line of attachment extends above the origin of the long head of the biceps from the supraglenoid tubercle (Fig. 18.6). On the humeral (which is also the distal) aspect, the capsule is attached to the head of the humerus just beyond the articular surface, i.e. to the anatomical neck and medial to the tubercles. However, on the inferior aspect, the line of attachment extends downwards onto the medial surface of the surgical neck.

When the arm is by the side of the trunk, the capsule is lax and its lower part forms a redundant fold. When the arm is abducted, the capsule becomes pulled up and is taut, thus making the fold disappear.

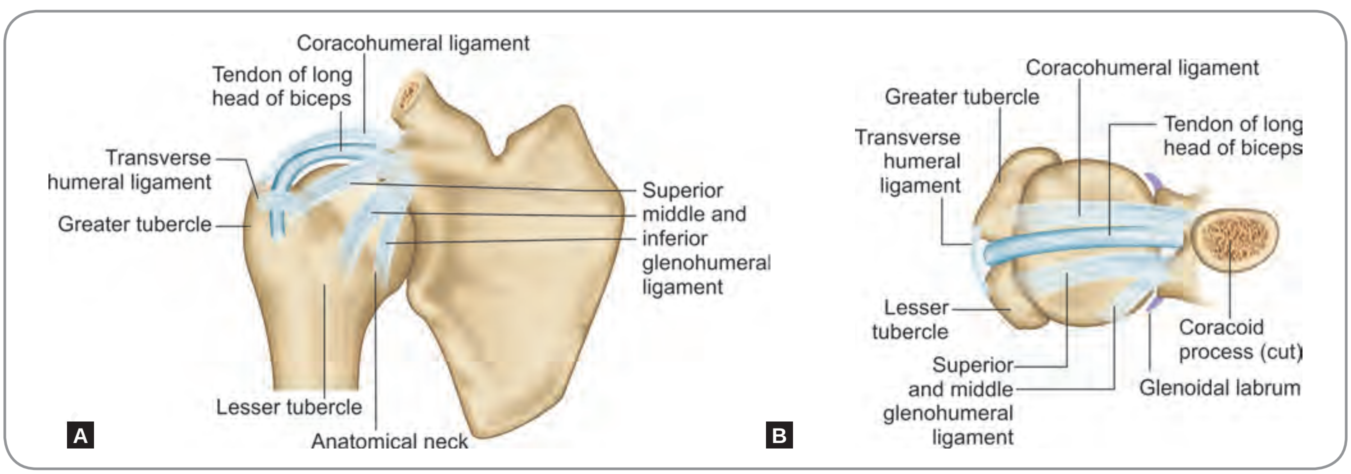
There are two openings in the capsule. One is at the attachment between the greater and lesser tubercles; the opening leads to the intertubercular sulcus and the tendon of long head of biceps escapes through it. The other opening is in the anterior portion of the capsule immediately under cover of subscapularis tendon; through this opening the joint cavity communicates with the subscapular bursa.

Most of the fibres of the capsule run longitudinally; a few fibres run transversely around the capsule

Ligaments: The ligaments (Figs 18.7A and B) of the shoulder joint are:

- Glenoidal labrum;
- Transverse humeral ligament;
- Glenohumeral ligament;
- Coracohumeral ligament;
- Coracoacromial ligamemt.

- ***Glenoidal labrum:*** Also called the labrum glenoidale. This is a fibrocartilaginous structure attached to the glenoidal margin. It deepens the glenoidal cavity, though only slightly The labrum is triangular in cross section, the base of the triangle being attached to the glenoidal margin The apex is free. Where the long head of biceps arises from the supraglenoidal tubercle, the tendon is fused to the labrum.
- ***Transverse humeral ligament:*** It is a bundle of transverse fibres of the capsule that stretches between the greater and lesser tubercles of the humerus. It converts the intertubercular sulcus into a canal through which the tendon of the long head of the biceps leaves the joint cavity.
- ***Glenohumeral ligaments***: These are three thickened bands of the longitudinal fibres of the capsule. They are visible on the internal aspect of the capsule and not on the external aspect. Named the superior, middle and inferior glenohumeral ligaments, they are attached medially to the upper part of the anteromedial margin of the glenoid cavity and are fused with the glenoidal labrum. Laterally they fan out to get attached to the humerus. The ***superior ligament*** is thus attached to the upper part of the labrum close to the tendon of the long head of biceps and passes along the medial side of the same tendon to reach the upper part of the lesser



Figs 18.7A and B: Ligaments of the shoulder joint – Scapula and humerus are viewed **A.** From the front and **B.** From above

tubercle of humerus. The ***middle ligament*** is attached to the upper part of the anterior border of the labrum and extends to the lower part of the lesser tubercle. The ***inferior ligament***, usually the most well developed of all the three, extends between the middle of the anterior border of glenoidal labrum and the lower part of the front of anatomical neck. The opening in the fibrous capsule that communicates with the subscapular bursa is between the superior and middle ligaments.

The aforementioned three ligaments of the shoulder joint can be considered as 'intrinsic ligaments' because all of them are either condensations of the capsule or intracapsular.

The joint also has two accessory ligaments which play an important role in the functioning of the joint.

- ***Coracohumeral ligament:*** This is an accessory ligament on the superior aspect. Medially it is attached to the lateral side of the root of the coracoid process (above the supraglenoid tubercle) and laterally to the superior aspect of the anatomical neck and adjacent aspect of the greater tubercle of the humerus. Though separately seen medially, it blends with the supraspinatus tendon and the joint capsule on the lateral aspect. It is therefore sometimes described as a thickening of the superior part of the capsule. The ligament greatly enhances the strength of the joint capsule whose upper part is under tension when the arm is hanging by the side of the trunk.
- ***Coracoacromial ligament:*** This ligament is considered as an accessory ligament of the shoulder joint because of its location and close proximity to the joint. Though it does not have a direct connection to the joint capsule, it forms a horizontal shelf above it. It is triangular in shape; the base is attached to the lateral border of the horizontal part of the coracoid process; the apex is attached to the tip of the acromion in front of the acromioclavicular joint. The middle portion of the ligament is thin and weak but its margins are strong.

The position and relations of the coracoacromial ligament are important. The ligament is covered on its superior aspect by the deltoid muscle. On its inferior aspect, it is separated by the subacromial bursa from the supraspinatus tendon and the shoulder joint which is below the tendon. Thus, the acromion and coracoacromial ligament form an arch which runs over the upper part of the shoulder joint. When force is transmitted upwards along the humerus, the head of humerus is pressed against this protective osseofibrous arch (joint capsule, supraspinatus fibres and tendon and the subacromial bursa intervene between them ofcourse).

Synovial membrane: The synovial membrane lines the fibrous capsule, covers both sides of the glenoidal labrum and the nonarticular parts of the humerus enclosed within the capsule. The tendon of the long head of the biceps is enclosed in a tubular sheath of synovial membrane; this sheath is prolonged, for some distance, into the intertubercular sulcus. The synovial membrane a so protrudes through the opening in the anterior aspect of the capsule and communicates with the subscapular bursa. Rarely, the membrane may protrude through a small opening on the posterior aspect of the capsule and forms a small bursa underneath the infraspinatus tendon.

Factors Contributing to the Stability of Shoulder Joint

The articular surfaces of glenoidal cavity and humerus are disproportionate. The total area of the glenoidal cavity is just about one-third of the area of the humeral head. This disproportion along with the shallowness of the glenoidal cavity places the humeral head at a great risk of dislocating from the glenoidal cavity. However, the anatomical configuration and position of the bones of the joint are essential for according mobility to the joint It can be well understood that development of mankind and civilisation of humanity depend upon the ability of the upper limb to execute various movements. Hence, several additional features contribute to the stability of the joint without compromising its mobility.

Rotator cuff: The tendons of supraspinatus (superiorly), subscapularis (in front) infraspinatus and teres minor (behind) blend with the fibrous capsule of the joint. These muscles contract and give a compressive force such that the head of humerus is held in contact with the glenoid cavity during movements of the shoulder joint. They are collectively called the rotator cuff or the musculotendinous cuff or the articular muscle group or SITS cuff The rotator cuff gives stability on the lateral aspect and prevents the capsule from getting impinged between the articular surfaces during movements.

Deepening of the joint cavity because of glenoidal labrum.

Coracoacromial arch: The osseofibrous arch formed by the coracoid and the acromion processes, along with the coracoacromial ligament prevents upward displacement of the humerus.

Long head of Biceps supports the superior aspect of the joint.

Long head of the triceps and teres major: The inferior aspect of the joint capsule is weak and is unsupported by muscles. Though not required when the arm is by the side, support will be needed to this aspect when the arm is raised up. The long head of triceps and teres major get applied to the inferior aspect during such circumstances and provide support.

Bursae Around the Joint

The shoulder joint is surrounded by a number of bursae. They facilitate movements between structures surrounding the joint. They are as follows:

Subscapularis bursa (between the tendon of subscapularis and joint capsule).

Infraspinatus bursa (between the tendon of infraspinatus and joint capsule).

Subacromial bursa (between the supraspinatus and coracoacromial arch and extends laterally between deltoid and greater tubercle of humerus). It is the longest bursa of the body and does not communicate with the joint cavity.

Other non communicating, inconsistent bursae are present one above the acromial process, one between capsule and coracoid process, one behind the coracobrachialis, one between teres major and long head of triceps and one behind latissimus dorsi.

Relations

- ***Anteriorly:*** Subscapularis, axillary vessels and brachial plexus.
- ***Posteriorly:*** Infraspinatus and teres minor.
- ***Superiorly:*** (from deep to superficial) supraspinatus, sub acromial bursa, coracoacromial ligament and deltoid.
- ***Inferiorly:*** Long head of triceps, axillary nerve and posterior circumflex humeral vessels.

Blood supply: Arterial supply to the joint is from the branches of anterior circumflex humeral, posterior circumflex humeral and suprascapular arteries.

Nerve supply: Branches from suprascapular, axillary and lateral pectoral nerves supply the joint.

Movements

- ***Orientation of the scapula and its effect on the shoulder joint:*** To understand the movements at the shoulder joint (Table 18.2) it is necessary to know that the scapula is placed obliquely (in relation to the wall of the thorax) so that its costal surface faces forwards ***and medially***, while the dorsal surface faces backwards ***and laterally***. Because of this, the glenoid cavity does not face directly laterally, but faces ***forwards and laterally***. Hence, the plane of the joint is set obliquely to the transverse plane of the body.

As the movements of the arm are described with reference to the plane of the scapula (and not in relation to the trunk) the definition of some of the movements is somewhat different from that for other joints In the neutral position the arm hangs vertically by the side of the trunk. Flexion and extension take place in a plane ***at right angles to the plane of scapula***. Thus, in ***flexion,*** the arm moves forward ***and somewhat medially***. Reversal of this movement (i.e. bringing it back to the side of the trunk) is ***extension***. Continuation of extension beyond the vertical position of the arm (taking it back and laterally) is called ***hyperextension***.

The movements of abduction and adduction take place ***in the plane of the scapula***. In abduction the arm moves laterally, and somewhat forwards. After reaching the horizontal position, the movement can be continued to raise the arm to a vertical position; this is referred to as ***overhead abduction***. Bringing the arm back to the neutral

Table 18.2: Movements at shoulder joint—from position of pendency i.e., arm by the side of trunk

Movement	Muscles producing	Possible extent	Factors limiting
Flexion	Clavicular head of pectoralis major and anterior fibres of deltoid—assisted by biceps and coracobrachialis—supraspinatus may also contribute	About 90°	Tension in the antagonists; after 90°, various factors operate to cause elevation of the arm, which continues from flexion
Extension	Posterior fibres of deltoid—assisted by teres major, latissimus dorsi and long head of triceps—sternal head of pectoralis major may also assist	About 45°	Tension in the antagonists
Abduction	Deltoid (middle fibres)—assisted by supraspinatus The supraspinatus muscle initiates the movement and holds the humeral head against the glenoid; then, the deltoid contracts and abducts.	180°; pure glenohumeral till 90–100°; then aided by scapular rotation	Impingement of the greater tubercle on the coracoacromial arch; after reaching the horizontal position, lateral rotation occurs to continue abduction which leads to elevation
Adduction	Pectoralis major and latissimus dorsi—assisted by teres major, teres minor and long head of triceps—posterior fibres of deltoid and coracobrachialis may also contribute	About 45° across the chest	Tension in the coracohumeral ligament
Medial rotation	Subscapularis—assisted by pectoralis major, anterior fibres of deltoid, latissimus dorsi and teres major	About 55°	Tension in antagonists and contact of various surrounding structures
Lateral rotation	Infraspinatus—assisted by teres minor and posterior fibres of deltoid	About 45°	Tension in coracohumeral ligament

position is ***adduction***. Further adduction brings the arm in front of the chest. Abduction and adduction take place partly at the shoulder joint, and partly by rotation of the scapula.

The rotatory movements of the arm are ***medial rotation*** and ***lateral rotation*** Rotation of the humerus that carries the flexed forearm medially is medial rotation. The opposite movement in which the forearm is carried laterally is lateral rotation. Any muscle passing from the trunk (or scapula) to the front of the humerus will be a medial rotator. A muscle passing to the back of the humerus will be a lateral rotator.

- ***Axes and planes of movements:*** The shoulder joint is of the ball and socket variety and is capable of wide range of movements around axes which pass through the centre of the humeral head. As is customary, three perpendicular axes are described, namely, the transverse (for flexion-extension movements), the anteroposterior (for adduction–abduction movements) and the vertical (medial and lateral rotation movements) axes Circumduction is a combination of anteroposterior and lateral movements; it occurs when the arm swings around a cone whose apex is at the humeral head.

The axes of the shoulder joint (except the vertical axis) do not conform to the regular position of such axes but are shifted in relation to the scapular orientation described above. Thus, the sagittal plane of the shoulder joint is inclined 45° posterolateral to the median plane of the body; the coronal plane of the joint is the same as the 'plane of scapula' which is perpendicular to the sagittal plane of the joint. Movements in the plane of scapula do not cause torsion of the joint capsule. Supraspinatus, infraspinatus, subscapularis and teres minor muscles function in this plane.

Association of Movements

- Movements at the shoulder joint provide the free upper limb with a lot of mobility. However, these movements are accompanied by movements of the shoulder girdle. The total movement of humerus that we are able to see is a combination of movements at the shoulder joint, movements of the scapula and movements of the clavicle. Association of all these movements not only increases the mobility of the free limb but also increases the power and force of its movements.
- Abduction of humerus is assisted by lateral rotation. If the arm is abducted without rotation, the movement is restricted by two factors: (1) exhaustion of the available articular surface, (2) contact of the greater tubercle with the coracoacromial arch. When abduction is effected after lateral rotation, the tubercles rotate posteriorly and impingement with the coracoacromial arch is prevented; the greater tubercle passes under the acromion This also causes more articular surface to be available leading to continued elevation of the arm.
- ***Scapulohumeral rhythm:*** In overall abduction-elevation movements of the arm, a ratio of 2:1 is seen. For every 3° of elevation, 2° take place at the glenohumeral (shoulder) joint and 1 degree occurs at the scapulothoracic (functional) joint. The first 30° of arm abduction is without any scapular motion. After this, scapular motion contributes to the abduction-elevation movement. When the upper limb is elevated to that level where the limb is by the side of the head (180° = it is both 180° of abduction and 180° of flexion), 120° would have occurred at the glenohumeral joint and 60° at the scapulothoracic joint. This is referred to as the 'scapulohumeral rhythm'.
- Middle fibres of deltoid and supraspinatus are involved in abduction of arm. Supraspinatus initiates the movement and then holds the humeral head against the glenoid. Deltoid then contracts to produce abduction. When the arm is by the side of the trunk, deltoid (especially its middle fibres) lies parallel to the humerus and its pull will not be able to abduct the arm. Therefore, if supraspinatus does not cause the initial movement, deltoid will not be able to continue abduction. First 15° to 30° of abduction is brought about by supraspinatus, midrange abduction till 120° is done by acromial fibres of deltoid and the remaining abduction by trapezius and serratus anterior.
- ***Elevation of the upper limb:*** The free upper limb can be raised from its dependent position (hanging by the side of the trunk) to a vertical position (vertical upwards on the side of face) and this goes through a movement of 180°. This vertical position is achieved through flexion (flexion till 90–100° and subsequent elevation) or abduction (abduction till 90° and subsequent elevation; this elevation is also called overhead abduction). During elevation, the sternoclavicular and acromioclavicular joints act along with the shoulder joint. Apart from the scapulohumeral rhythm (mentioned above), clavicular movements also take place. When elevation starts after 90 degree flexion or 90 degree abduction clavicle rotates backwards around its own long axis and its lateral end rises up. This clavicular movement helps in scapular rotation which in turn leads to humeral movement. Restriction of clavicular and scapular movements cause impairment of humeral elevation. In the early phase of elevation, clavicular movements are maximal at the sternoclavicular joint; in the terminal phase, they are maximal at the acromioclavicular joint.

Added Information

- Tendon of long head of biceps is dubbed the super stabiliser of the joint. It holds the head of humerus tightly against the glenoid cavity. It also plays the role of an accessory ligament when the humerus is laterally rotated; in this position the tendon crosses the upper part of the humeral head and steadies the latter against the glenoidal cavity. It steadies the humeral head and prevents its impingement on the acromion when the deltoid contracts.
- The coracohumeral ligament is considered as a separated part of the tendon of pectoralis minor.
- The strength of the shoulder joint does not depend on bony structure or ligaments. The muscles around the joint provide with necessary support and strength. Again, the long muscles are not of much importance, since they are concerned with movements. The small muscles perform the most important task of retaining the head of humerus within the glenoid socket. They are assisted by the coracoacromial arch, which resists an upward displacement of the humeral head.
- The coracoacromial arch along with the subacromial bursa forms a firm but resilient 'secondary socket' for the head of humerus.
- Downward dislocation of shoulder is prevented by a complex locking mechanism that is based on the following factors: (a) slope of glenoid fossa, (b) tightening of the upper part of the fibrous capsule and (c) contraction of supraspinatus muscle.
- The subacromial bursa, which is between the acromion and the tendon of supraspinatus, is more extensive than what is expected or its name suggests. It extends between the deltoid muscle and the greater tubercle of humerus. This is to facilitate passage of the greater tubercle under the acromion during abduction.
- The rotator cuff muscles are also called ***alert ligaments*** of the joint since they perform the strengthening action of ligaments but are able to contract by virtue of their muscular fibres. They are not passive like other ligaments. They are sometimes called ***ligaments under control***.
- Supraspinatus and deltoid can be called the elevator muscles of the humerus. However, they will not be able to act unless the three 'anchors', namely, subscapularis, infraspinatus and teres minor hold the humerus in position. These anchors are actually depressors. Therefore, a force couple is formed; one group being elevators and the other depressors.

Clinical Correlation

- ***Dislocation:*** The shallowness of the glenoid cavity and the laxity of the capsule give the shoulder joint great freedom of movement; but this is at the expense of stability. So of all joints of the body, the shoulder joint is the most liable to dislocation. Sudden violent force to an abducted humerus tilts the humeral head downwards; the head tears through the weak inferior part of the capsule; due to the action of the strong flexors and adductors, the head of humerus is displaced forwards and comes to lie in the infraclavicular fossa just below the coracoid process. This is ***anterior*** or ***subcoracoid*** dislocation. Less commonly the head of

contd...

Clinical Correlation *contd...*

the humerus may be displaced backwards. When this happens the arm is fixed in a medially rotated position. It will be recalled that the capsule of the shoulder joint is least supported inferiorly. Hence the head of humerus first passes downwards and then moves anteriorly or posteriorly. Downward dislocations (subglenoid dislocation) at the shoulder carry the risk of injury to the axillary nerve, to the radial nerve, to the brachial plexus (especially the posterior cord) or to the axillary artery. Sometimes dislocation of the shoulder joint may occur repeatedly (***recurrent dislocation***), and may occur even with trivial force.
- In recurrent dislocations, a first episode of acute dislocation would have already occurred. Recurrence occurs in young adults who were treated for dislocation, but have been immobilised insufficiently. Subsequent dislocations are reduced by the patient himself. The reason behind is either the Bankart's lesion or the Hill Sach's lesion. In the former, there is improper healing of glenoidal labrum, which gives a pouch like space in front of the neck of scapula, into which head of humerus dislocates. In the latter, a depression is formed in the head of humerus following compression during the first injury. During abduction, this depression may get hitched into the posterior margin of glenoidal labrum.
- ***Subacromial bursitis:*** The ***subacromial bursa*** lies deep to the coracoacromial arch and the adjoining part of the deltoid muscle. This bursa facilitates abduction at the shoulder joint. During over-head abduction, the greater tuberosity slips below the bursa and comes to lie deep to the acromion When the bursa is inflamed (***subacromial bursitis***), pressure over the deltoid, just below the acromion elicits pain; but pain cannot be elicited after abduction (as the bursa is now under the acromion). This is called ***Dawbarn's sign*** and is usually associated with inflammation of the supraspinatus tendon. Chronic inflammation of the bursa may produce calcification leading to the condition called calcific scapulohumeral bursitis. Calcium deposits in supraspinatus tendon are seen frequently with no associated bursitis. The condition is extremely painful especially during abduction of arm. However, the deposits may irritate the overlying subacromial bursa causing a secondary bursitis.
- ***Rotator cuff disorders:*** These can be of two types: (1) impingement syndromes and (2) tendinopathies.
  1. ***Impingement syndrome or painful arc syndrome:*** This condition is characterised by pain typically occurring on abducting the shoulder between 60° and 120°. It occurs in rotator cuff impingement, where osteoarthritic thickening of coracoacromial arch, inflammation of the cuff or prolonged overuse results in the impinging of rotator cuff tendons against coracoacromial arch, when humerus is abducted. In the adducted position there is no pain because the lesion is away from the acromion. During 60° to 120° abduction, the tendons are in contact with the acromion.

     The most commonly involved muscle in such disorders is the supraspinatus. The supraspinatus tendon passes underneath the acromion. The space through which the tendon passes is of limited dimensions. Swelling

contd...

Clinical Correlation ***contd...***

of the muscle due to repeated friction, excessive fluid collection in the subacromial bursa or bony deformities in the acromion can all lead to impingement on arm abduction.

2. ***Tendinopathy:*** The supraspinatus tendon does not have a robust blood supply. Repeated trauma and continuous friction may cause calcium deposits in the tendon. The condition is extremely painful.

- ***Rupture of rotator cuff:*** Though other muscles of the group can be involved, the most mommon muscle to be affected is the supraspinatus. When the tendon is damaged (as noted above) it may undergo partial or complete tears. It also occurs in old persons because of degeneration with age. The patient is unable to initiate abduction at the shoulder joint, but can maintain it once the arm is partial y abducted. Even daily activities like combing the hair becomes difficult.

  Strain of the supraspinatus is common in persons who have to work for long periods with the arms in slight abduction (e.g. typists). It can cause distressing pain.

  The subacromial bursa (clinically referred to as the subacromial subdeltoid bursa) gets inflamed when there is supraspinatus tendinopathy. Movements at the shoulder joint are then affected.
- ***Periarthritis shoulder:*** In this condition, there is pain and progressive limitation of movements of the shoulder. Causes are idiopathic or secondary to diabetes, infections and myocardial infarction. Abduction and late al rotation are usually impaired but in severe conditions, the entire rotator cuff can be involved leading to frozen shoulder. The shoulder appears to be frozen (not able to move properly) because fibrosis and scarring of shoulder capsule, rotator cuff, deltoid and subacromial bursa occur.
- ***Sprengel's shoulder:*** This is a condition in which the scapula (and therefore the shoulder joint) is placed higher than normal.
- ***Shoulder pain:*** Injuries and inflammation of the shoulder joint produce pain and limitation of movement. The muscles around undergo spasm thus immobilising the joint and reducing pain. However, disease elsewhere can also lead to shoulder pain. Diseases of spinal cord, vertebral column, diaphragm and peritoneum can all cause shoulder pain through various nervous connections.
- ***Tear of glenoidal labrum:*** The glenoidal labrum may suffer a tear due to forced movements. This commonly occurs in sportspersons involved in throw games. Consequent dislocation of the shoulder may also occur.

EVOLUTIONARY MORPHOLOGY

Evolutionary considerations of the shoulder joint: Erect posture and bipedal gait in the human beings have given the upper limbs complete freedom to perform a wide range of movements. However, several structural adaptations in the shoulder and elbow regions contribute to this ability.

In the apes, the glenoidal cavity faces cranially; this places the forelimb (upper limb) in an overhead position which is necessary for climbing trees and arboreal life. The shoulder joint is thus superior to the rest of the trunk and the scapulae are more laterally placed. The clavicle is short and placed obliquely; a fairly large-sized muscle called the atlantoclavicularis connects the atlas bone and the lateral part of the clavicle; pull of this muscle elevates the clavicle in association with the overhead position of the limb. This is aided by a large-sized supraspinatus which occupies a very large supraspinous fossa.

In some ape-like hominoids, the scapulae are on the sides of the trunk; the glenoid faces forward. The limb can move freely on the sides of the trunk. Manipulating objects in front is possible but a complete 'full circle' range that includes the posterior aspect as in the human beings is not possible.

As the human beings attained an erect posture and started walking about on earth (thus leaving the arboreal habit), it became necessary for the upper limb to remain closer (but not too close) to the trunk. 'Overhead position' had to be lost so that the limb gains more mobility. The shoulder descends; scapulae occupy dorsal position; the glenoidal cavities face more laterally. In addition, the glenoids also flatten a little resulting in shallower sockets. To accommodate for the changes happening in the shoulder area and in the scapulae, the clavicles lengthen and come to lie horizontal. The medial part of the clavicle curves more to keep the bone horizontal and the clavicle carries the scapulae lateralwards. Reciprocal modifications occur in the humerus. The head of humerus becomes more spherical; the intertubercular sulcus becomes shallower in order to ensure smooth and hindrance free circulatory movements Insertions of rotator cuff muscles come closer to each other.

Another important change that occurs is the increase in humeral torsion.

All the changes which occur in the shoulder region bring the shoulder joint laterally out thus helping in providing the joint complete freedom for circulatory movements. The upper limb in the humans can travel around a full circle.

- As a consequence, humans have acquired the 'throwing' ability. This ability had given a selective benefit to humankind; early men were able to throw stones and other weapons at their wild enemies and thus protect themselves;
- 'Throwing' is a unique ability exclusive to humans;
- The humerus undergoes medial rotation during the mid and late phases of throwing; this rotation is the fastest of all human movements.

In about 3% of individuals, a small muscle running between the transverse processes of cervical vertebrae and the lateral end of clavicle is found; it is called the levator claviculae; it is a morphological remnant of the atlantoclavicularis muscle present in apes and some monkeys.

ELBOW JOINT

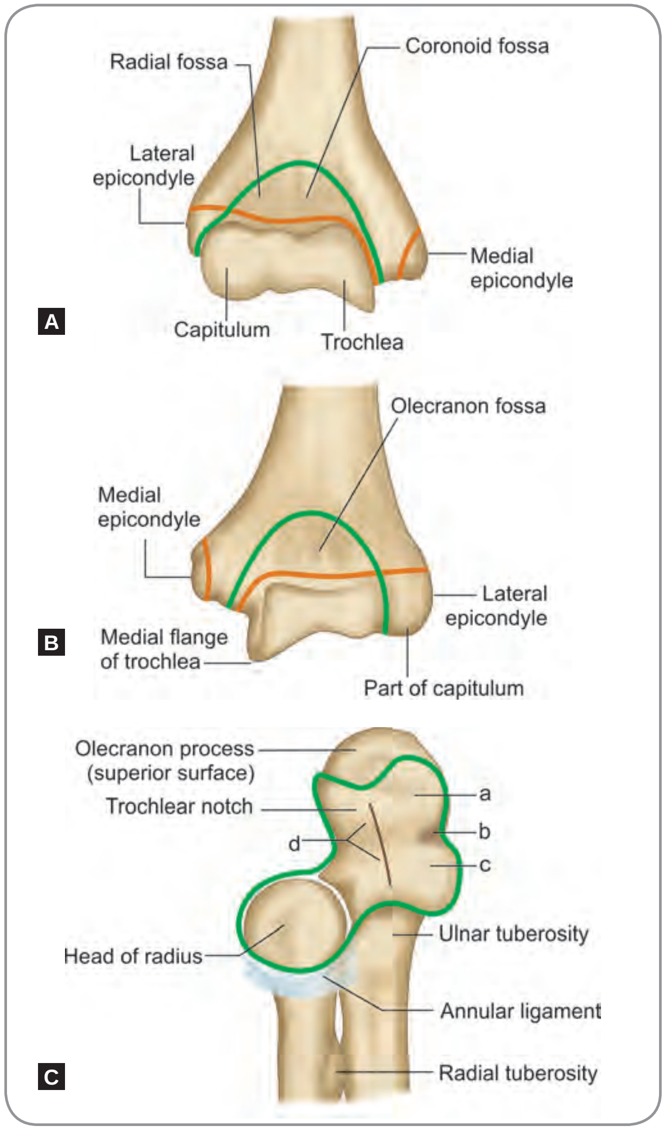
The elbow joint is a synovial joint of the hinge variety between the humerus and the bones of the forearm. It is also a compound joint as more than two bones take part in it.

Articular surfaces: The elbow actually has two articulations, namely; (1) humeroulnar and (2) humeroradial. The trochlea of the humerus articulates with the trochlear notch at the upper end of ulna (***humeroulnar part***) and the capitulum of the humerus articulates with the concave upper surface of the head of radius (***humeroradial part***). The single cavity of the joint is continuous with that of the ***superior radioulnar joint***, the two sharing a common synovial membrane. All the three mentioned above (the two parts of the elbow joint and the proximal radioulnar joint) are collectively referred to as the ***cubital articulation***

1. ***Humeroulnar part:*** The trochlea extends from the lower border of the *coronoid fossa* on the front of humerus, around the inferior end of the bone to the lower border of the *olecranon fossa* on the posterior aspect. It is also not bilaterally symmetrical Its medial flange is larger than the lateral and projects downwards about 6 mm below the *lateral flange*. As a result, the lower edge of the trochlea is not horizontal, but passes downwards and medially The trochlear notch on the ulna consists of an upper part present on the anterior surface of the olecranon and a lower part present on the upper surface of the *coronoid process*. The articular surface of the trochlear notch is divided into medial and lateral parts by a ridge that projects forwards (Figs 18.8A to C).
2. ***Humeroradial part:*** The capitulum of the humerus is a spheroidal area on the anterior and distal aspects of the bone. It articulates with the concave superior surface of the radial head. The raised margin of the radial head articulates with capitulotrochlear groove of the humerus.

   The articular surfaces, as is regular in a synovial joint, are covered with articular cartilage. The articular cartilage covering the composite capitulotrochlear surface on the humerus is a continuous stretch, but the one covering the trochlear surface of the ulna is interrupted along a transverse line in the deeper part of the trochlear notch. The cartilage covering the radial concavity is continuous with that covering the sides of the radial head, which actually is part of the superior radioulnar joint.

The ulnar and radial articular surfaces are not completely congruent with the corresponding humeral surfaces. However, in a semiprone position, maximal contact between the surfaces is achieved. Hence, this is the most stable, most relaxed and most convenient position of the joint.



Figs 18.8A to C: Attachment of the capsule (thick green line) of the elbow joint to the humerus **A.** Anterior aspect **B.** Posterior aspect – Epiphyseal lines are shown in thick orange line **C.** Lower articular surfaces of elbow joint and the capsular attachment – The radius and ulna are viewed from the antero-superior aspect

b. The indentation or ridge that divides the upper and lower parts of articular surfaces a & c. The medial parts which fit against trochlear flange d. vertical ridge

Dissection

It is easy to dissect and study the elbow and superior radioulnar joints in a free upper limb.

Clean up and define the brachialis, triceps and supinator muscles (or their remnants). Remove them carefully without damaging the elbow joint or its capsule. Define the ulnar collateral, radial collateral and annular ligaments The anterior and posterior parts of the joint capsule are weak. Make a transverse incision in the anterior part of the capsule. The articular surfaces can now be seen and studied. Study the annular ligament and cut through to see the quadrate ligament.

Articular capsule: On the humeral side, the articular capsule is attached anteriorly to the superior margins of the coronoid and radial fossae and to the front of medial and lateral epicondyles; posteriorly it is attached to the superior margin of the olecranon fossa. As a result, considerable nonarticular areas of the humerus are included within the joint cavity. These include the coronoid and radial fossae in front, the olecranon fossa behind and the flat medial surface of the trochlea. On the medial aspect of the front of the forearm, the capsule is attached to the coronoid and olecranon processes of the ulna around the margins of the articular surface. On the lateral aspect, it is not attached directly to the radius, but to the anterior part of the annular ligament of the superior radioulnar joint which encircles the head of the radius. On the posterior aspect, one set of capsular fibres stretch from the margins of the olecranon fossa of humerus to the sides of the olecranon of the ulna; the other set extends between the lateral epicondyle and the posterior border of the radial notch of ulna.

Ligaments: The joint capsule is thin anteriorly and posteriorly, but is thickened on the medial and lateral sides to form the ulnar and radial collateral ligaments (as is common in any hinge joint).

- ***Ulnar collateral ligament:*** Otherwise called the medial ligament of the elbow, it is triangular in form, the apex of which is attached to the medial epicondyle of humerus and the base to ulna. It has three thickened bands, namely, (1) the anterior, (2) posterior and (3) transverse. The anterior band extends from the medial epicondyle to the medial margin of the coronoid process; the posterior band from the medial epicondyle to the medial side of the olecranon. The transverse band connects the ulnar attachments of the anterior and posterior bands. The base of the thinner triangular portion of the ligament between the anterior and posterior bands is also attached to the transverse band. The lower edge of the transverse band is very often free and a small pouch of synovial membrane may protrude through the gap, especially during movements of the elbow (Fig. 18.9).
- ***Radial collateral ligament:*** Otherwise called the lateral ligament of the elbow, it is attached at its upper end to the lateral epicondyle of the humerus and to the annular ligament of the superior radioulnar joint at its lower end (Fig. 18.10).

  A space exists between the oblique band and the bone, and synovial membrane may bulge out through this gap in the attachment of the capsule.

Synovial membrane: The synovial membrane of the joint is extensive; it lines the fibrous capsule and covers the pads of fat over the nonarticular areas like the radial, coronoid and olecranon fossae. On the distal aspect, from lining the fibrous capsule, it is prolonged on the deeper surface of the annular ligament. From there, it gets reflected to the neck of radius on the lateral side and to the lower border of the radial notch on ulna on the medial side. Apart from the synovial cavity of the elbow joint being continuous with the synovial cavity of the proximal radio ulnar joint, there are no other openings or lacunae in the synovial cavity or the articular capsule of the elbow joint; but the synovial membrane may out pouch beneath the transverse band of the ulnar collateral ligament, beneath the inferior border of the annular ligament or above the olecranon fossa.

Fig. 18.9: Attachments of ulnar collateral ligament of the elbow joint

Fig. 18.10: Attachments of the radial collateral ligament of the elbow joint

Relations

- ***Anteriorly:*** Brachialis muscle, biceps brachii tendon, median nerve and brachial artery;
- ***Posteriorly:*** Triceps muscle, bursa between the joint capsule and the muscle;
- ***Medially:*** Ulnar nerve which lies behind the medial epicondyle and crosses the ulnar collateral ligament;
- ***Laterally:*** Common extensor tendon and supinator muscle.

Added Information

- When the elbow joint is extended, the supinated forearm passes somewhat laterally (relative to the arm) due to the carrying angle, but when fully flexed, the forearm lies over the arm. In this position of pronation, the shoulder, the elbow and the wrist are all in line with one another and all force is cumulated. This may be correlated with the fact that most acts calling for precision and strength (including all pulling and pushing movements) are performed with the forearm pronated. The obliquity in the line of the elbow joint may be regarded as a device to ensure that the arm and forearm are in line in pronation.
- The collateral ligaments are tense in all positions; but the anterior parts are more tense in extension and the posterior parts in flexion.
- Of the three bands of the ulnar collateral ligament, the anterior band is rounded and strong; the posterior band is flattened and weak; the transverse band, by virtue of its position, tends to deepen the socket for the trochlea.
- The joint surfaces are in maximum contact when the forearm is flexed to about 90° and when the forearm is semipronated. This is the position of greatest stability; it may be noted that this is the position in which the limb is naturally held while free or while engaged in activities.
- The fibrous capsule and the synovial capsule are not co-extensive throughout the joint. In the coronoid, radial and olecranon fossae, the synovial capsule is much less in size. The space between the fibrous capsule and the synovium is filled with pads of fat which remain fluid in consistency at body temperature.
- In a child, the head of radius is smaller than its neck. So, sudden traction on the child's forearm can cause the radius to dislocate downwards. This causes a very painful condition called 'pulled elbow'.
- The chief flexors are biceps brachii and brachialis. Brachioradialis can act even when the chief flexors are paralysed and produce rapid flexion. During slow flexion, the chief flexors are assisted by brachioradialis and pronator teres.
- Of the four (brachialis, brachioradialis, biceps brachii and pronator teres) muscles which produce flexion at the elbow, two act on the radioulnar joints too. Biceps is a supinator and pronator teres is a pronator.
- The biceps brachii, as a flexor of the elbow, can act the best only when the forearm is supinated; it can act a little in semipronation and very little in pronation. Similarly, its supination action on the forearm cannot be achieved in extension of the elbow.
- Though the brachioradialis is a powerful flexor of the elbow, it acts the best only in semipronation. The attachments of this muscle are far removed from the transverse axis of the joint. Thus, it has a mechanical advantage which accords more power.
- Muscles which are attached close to the axis of the joint do not enjoy mechanical advantage and so, (e.g. pronator teres) are not powerful.
- Both the chief flexor and the extensor (biceps and triceps respectively) act on the humeroulnar component of the joint.

contd...

Added Information *contd...*

- Special nervous relations of the joint: Five nerves come in close contact with the joint—Musculocutaneous nerve – lies anterior and separated from the joint by the brachialis muscle; median nerve – lies anteromedial and separated by brachialis; radial nerve – (or its branches) lies anterolateral and on the joint capsule; ulnar nerve – lies posteromedial and in contact with the ulnar collateral ligament; nerve to anconeus – lies posterolateral and close to the capsule.

Bursae Around the Elbow

Many parts of the elbow are subcutaneous. In addition, the elbow region itself is crowded with several structures The presence of buffering structures like the bursae, thus becomes important in this region and clinically significant. The bursae are as follows:

- ***Subcutaneous olecranon bursa:*** It is located between the olecranon and the skin in the subcutaneous tissue.
- ***Subtendinous olecranon bursa:*** It is located between the tendon of triceps and the olecranon. It is proximal to the attachment of the tendon to olecranon while the subcutaneous bursa is distal to the attachment.
- ***Intratendinous olecranon bursa:*** It is relatively rare and if present, is within the tendon of triceps.
- ***Bicipitoradial bursa:*** It is between the tendon of biceps and radial tuberosity.

Blood Supply

The elbow joint receives its ***blood supply*** from the arterial anastomosis around it.

Nerve Supply

The ***nerve supply*** is from nerves which cross the joint; twigs mainly from musculocutaneous and radial nerves supply, but twigs from ulnar, median and anterior interosseous nerves are also seen.

Clinical Correlation

- ***Dislocation of the elbow Joint:*** In this dislocation, the radius and ulna are usually displaced backwards and lateral y. It may be associated with fractures of the bones in the region (coronoid process of ulna, head of radius, capitulum or medial epicondyle of humerus). There is danger of injury to the brachial artery or to any of the nerves crossing the elbow. Posterior dislocations are common in children because the bony parts are yet to develop; avulsion of the medial epicondyle is also common because the medial ligament of the joint is stronger in children than the epiphysis-diaphysis union.
- ***Supracondylar fracture of humerus:*** It is a transverse fracture of the humerus above the level of the epicondyles. It is usually caused by fall on an outstretched hand with hyperextension at the elbow and dorsiflexion at wrist. It is common in boys who are less than 10 years of age. Brachial artery, median and ulnar nerves are prone to injury in this

contd...

Clinical Correlation *contd...*

fracture. The triceps pulls the distal fragment of the humerus posteriorly; this causes the brachial artery to be damaged by the irregular proximal fragment

- ***Bursitis and student's elbow:*** Repeated pressure over the olecranon process can cause inflammation of the ***olecranon bursa***. The condition is called ***student's elbow*** or ***miner's elbow.***
- ***Epicondylitis:*** Repeated contractions and overuse of the flexors and extensors cause strain on their origins at the epicondyles. Pain at the concerned epicondyle is the main symptom. It is resolved on rest. Depending on which group of muscles is involved, epicondylitis is subdivided into two.
  - ***Tennis elbow:*** This is a painful condition caused by strain on the common extensor origin by repeated contraction of extensor muscles. Pain is felt over the lateral epicondyle and the posterior aspect of the forearm.
  - ***Golfer's elbow:*** This is a painful condition caused by strain on the common flexor origin. Pain is felt over the medial epicondyle.
- ***Cubitus valgus:*** There is a lateral deviation of forearm and hence an increase in the carrying angle. Non-union or destruction of lateral epicondyle results in cubitus valgus. It causes stretching of ulnar nerve resulting in late onset paralysis called tardy ulnar palsy.
- ***Cubitus varus (Gunstock elbow):*** There is a medial deviation of forearm and hence reduction in carrying angle. The most common cause is supracondylar fracture during childhood.
- There is a relation between the two epicondyles and the olecranon process. In a semi flexed arm they are in the orientation of an isosceles triangle and they lie in a straight line in the extended arm. In dislocation of elbow joint, the olecranon process moves and the imaginary triangle is disrupted, whereas in supracondylar fracture of the humerus, the triangle is retained.
- ***Sideswipe injuries:*** These are fractures of either olecranon process, radius or ulna or comminuted fractures of humerus when an elbow projecting from a car or bus window gets injured.
- Osteoarthritis of the elbow is quite common. It is seen mostly in the dominant limb. The degenerative changes may produce small bony fragments which crowd the space within the limited joint cavity. Movements are then restricted.
- Radiological reading should be done with the fact in mind that normally, the medial epicondyle directs posteromedially and in the same direction as that of the head of humerus.
- ***Avulsion of medial epicondyle:*** This occurs in children and young adults when there is a fall and the elbow is abducted beyond normal. The ulnar collateral ligament is tensed

contd...

Clinical Correlation *contd...*

and pulls the epicondyle down. The main reason is the non-fusion of the epiphysis for medial epicondyle until the age of 20–22 (normal fusion occurs at about 14–16). The injury gains more importance because of the fact that the ulnar nerve can be pulled or stretched due to its proximity to the medial epicondyle.

- ***Fractured olecranon:*** This condition is often referred to as 'fractured elbow'. The olecranon is fractured due to a fall on the elbow; triceps contracts and the broken bit of olecranon is pulled up.

Movements

The elbow joint being a hinge, allows only flexion and extension movements (Table 18.3). Bending the elbow so that the front of forearm tends to touch the front of arm is flexion. Straightening the limb at the elbow is extension.

These ***movements*** occur around a transverse axis which is not 'really transverse' or at right angles to the long axes of humerus and bones of forearm. The axis passes through the humeral epicondyles and, due to the obliquity seen in the bone, downwards and medially. Yet another fact complicates the situation. The medial flange of the trochlea is larger than the lateral flange and projects downwards more. As a result, the lower edge of the trochlea is not horizontal, but passes downwards and medially. This results in the angulation between the long axis of arm and that of forearm. This angle of deviation of forearm from the axis of arm is about 10° to 15°; thus in the supinated position, the arm and the forearm form an angle called the 'carrying angle' of about 165° to 170° open laterally. The transverse axis of movement bisects the carrying angle. So, when the forearm is flexed, the carrying angle disappears and the arm and forearm come to lie in line with each other.

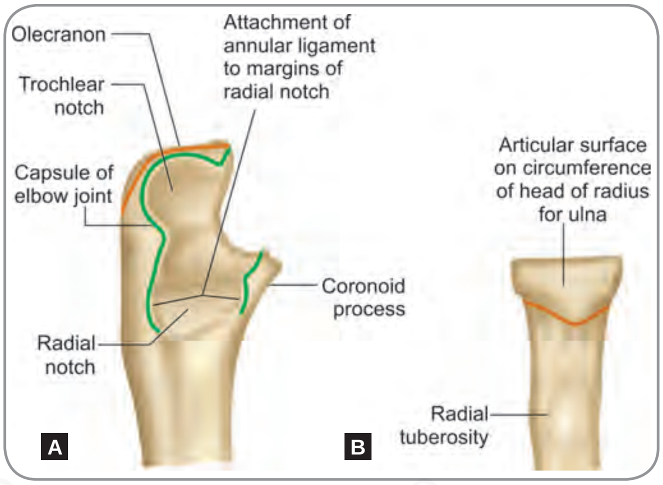
Surface marking: The elbow joint is located 2 to 3 cm inferior to the level of the medial and lateral epicondyles of the humerus.

RADIOULNAR JOINTS

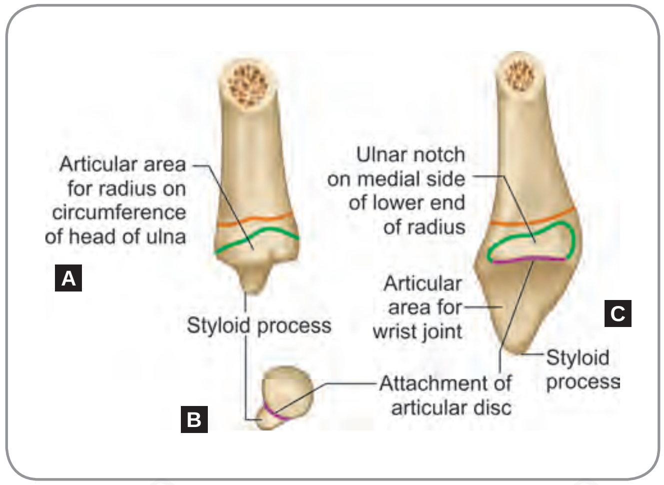
The upper and lower ends of the radius and ulna are joined to each other at the superior and inferior radioulnar joints. The shafts of the two bones are united by the interosseous membrane (sometimes called the middle radioulnar joint).

Table 18.3: Movements of elbow joint

Movement	Muscles Producing	Factors limiting	Other features
Flexion	Biceps brachii, brachialis and brachioradialis—assisted by pronator teres	Apposition of the forearm and arm; tension in the posterior muscles and collateral ligaments	Carrying angle is masked
Extension	Triceps—assisted by anconeus	Straight position of the limb; tension in the anterior muscles and collateral ligaments	Carrying angle is pronounced



Figs 18.11A and B: Articular surfaces of the superior radioulnar joint **A.** Upper end of ulna – lateral aspect **B.** Upper end of radius – medial aspect



Figs 18.12A to C: Articular surfaces and capsular attachments of inferior radioulnar joint **A.** Lower end of ulna – lateral aspect **B.** Lower end of ulna – inferior aspect **C.** Lower end of radius – medial aspect

Superior and inferior radioulnar joints: These are both synovial and of the pivot variety. At the ***superior radioulnar joint,*** the head of radius rotates within a ring formed by the radial notch of ulna and the annular ligament. The head of radius is circular and the radial notch of ulna is reciprocally concave. The articular cartilage on the radial notch of ulna is continuous with that on the trochlear notch; on the head of radius, the cartilage is on the superior surface and sides (Figs 18.11A and B). The annular ligament surrounds the circumference of the head of the radius and is attached anteriorly and posteriorly to margins of the radial notch of the ulna. It is continuous above with the capsular ligament of the elbow joint. The lower part of the ring formed by this ligament is slightly narrower than the upper part thus preventing the radius from slipping down. The cavity of the superior radioulnar joint is also continuous with that of the elbow joint. A thin ligament called the quadrate ligament stretches between the neck of the radius and the upper part of supinator fossa of the ulna Branches of median, ulnar, musculocutaneous and radial nerves supply this joint.

The ***inferior radioulnar joint*** is formed by articulation of the convex articular surface on the lateral side of the head of the ulna with the ulnar notch of the radius. The chief bond of union between the two bones is an ***articular disc*** which is triangular; its apex (directed medially) is attached to the ulna on a depression just lateral to the styloid process; its base is attached to the radius on the lower margin of the ulnar notch. Its upper surface forms part of the inferior radioulnar joint and articulates with the inferior surface of the head of the ulna. Its lower surface forms part of the proximal articular surface of the wrist joint. The cavities of these two joints are completely separated by the disc. The cavity of the inferior radioulnar joint is L-shaped; the vertical limb is between radius and ulna; the horizontal limb is between the ulna and the articular disc. A small protrusion of the synovial cavity called the sacciform recess extends upwards between the radius and ulna. The joint is supplied by twigs from the anterior interosseous nerve and deep branch of radial nerve (Figs 18.12A to C).

Middle Radioulnar Joint

The middle radioulnar joint is formed by the interosseous membrane and the oblique cord between the two bones.

- The interosseous membrane is a strong sheet of fascia which stretches between the interosseous borders of the two bones. Its fibres run medially and downwards from radius to ulna. Proximally the membrane does not completely close the gap and above the membrane is a small opening through which the posterior interosseous vessels pass from the anterior to the posterior aspect. Distally the membrane merges with the fascia over the muscles (especially the fascia on the dorsal surface of pronator quadratus) of the area. The distal part of the membrane is pierced by the anterior interosseous vessels.
- The oblique cord is a rounded fibrous band that stretches from the tuberosity of ulna to a little below the tuberosity of radius. Its direction is inferolateral.

Movements

Movements taking place at the radioulnar joints are those of pronation and supination. These are rotatory movements. Supination is when the forearm is held so that the palm faces forwards, the radius and ulna lie parallel to each other. In pronation, the forearm rotates (along with the hand) so that the radius crosses in front of the ulna, its lower end comes to lie medial to that of the ulna, the interosseus

membrane spirals and the palm faces backwards. The axis of movements is a line passing proximally through the head of radius and distally through the attachment of the articular disc to ulna. The movement is mainly by the radius, which rotates within the ring formed by the annular ligament and the ulna The lower end also moves around the ulna, carrying the hand along with it. Range of pronation is about 61°–66° and supination is 70°–77°. The distal end of ulna keeps changing its position during these movements; during pronation, when the radius is travelling forwards and medially, the ulna travels backwards and laterally thus going through the other half of the circle. During supination, when the radius moves backwards and laterally, the ulna moves forwards and medially. Since ulna is not stationary during pronation-supination movements, the axis of movements is also not fixed; it moves laterally in pronation and medially in supination.

Pronation–supination movements with an extended elbow are invariably associated with rotation of humerus at the shoulder; medial rotation with pronation and lateral rotation with supination. However, when the elbow is flexed, there is no accompanying humeral rotation. The muscles responsible for supination are the supinator and the biceps brachii. The latter can act only after the forearm has been semiflexed. Pronation is produced by the pronator quadratus and the pronator teres. Power is more in supination as it is an antigravity motion and because of the strength of biceps; most of the tightening and screwing instruments are manufactured in such a way that they could be operated best by the supination action of the right forearm (majority of world's population being right-handed).

Added Information

- In an extended forearm, the axis of humeral rotation and the axis of pronation-supination are in the same line; the forearm movements are supplemented by humeral rotation and so, it is possible to turn the hand through a range of about 340 to 360°.
- The interosseous membrane is taut in supination, semi-pronation and pronation of forearm (that is in all positions).
- During supination-pronation movements, hand is carried along with the lower end of radius. However, the central axis of forearm and hand is not altered. This is brought about by a small degree of abduction movement of ulna at the bone's lower end. Contraction of anconeus muscle brings about abduction of the lower end of ulna during supination. During pronation, movement of the distal end of radius causes abduction of ulna. These movements of ulna, though minimal and not seen clearly during naked eye examination of radius-ulna excursions, are important; they prevent the hand being carried away laterally during supination and medially during pronation. The hand is maintained in line with the axis of the forearm. They play a crucial role in keeping the hand in position without side-to-side slipping during repetitive movements of supination and pronation.

Dissection

The inferior radioulnar joint and wrist joint are studied together. After cleaning and identifying the flexor and extensor tendons of the wrist region, the capsule of the wrist is cleaned and defined Observe the palmar radiocarpal, palmar ulnocarpal, dorsal radiocarpal, radial collateral and ulnar collateral ligaments. Make a transverse incision in the dorsal part of the capsule of the wrist. Take a clear look at the articular disc and the articular surfaces. Cut the ligaments wherever necessary to view the details. Finally divide all the ligaments to see the distal radioulnar joint cavity.

Clinical Correlation

- Anterior dislocation of the head of the radius is usually associated with fracture of the upper part of the shaft of the ulna (***Monteggia fracture-dislocation***).
- In children, a sudden powerful jerk of the hand may pull the head of radius out of its normal position within the ring of the annular ligament. This is called ***subluxation of the head of radius*** (or ***pulled elbow***). The condition can also occur by lifting a child by the wrist. The displacement can be reduced by pushing the forearm upwards and then alternately pronating and supinating the forearm.
- Dislocation of the inferior radioulnar joint is usually accompanied by a fracture of the shaft of the radius (***Galeazzi fracture-dislocation***).
- ***Colles' fracture (Poutteau's fracture):*** This is the fracture of lower end of radius where the distal segment is displaced upwards and posterior (Dinner fork deformity). The cause is fall on an outstretched hand and is common in the elderly.

WRIST JOINT

The wrist joint (or the radiocarpal joint) is a synovial joint of the ellipsoid variety formed between the distal aspect of radius and the articular disc on one hand, and the proximal row of carpal bones on the other.

Articular surfaces: The concave proximal articular surface is formed by the distal end of the radius and the inferior surface of the articular disc of the inferior radioulnar joint Together, the surface is longer from side-to-side than before backwards. The distal articular surface is convex and is formed by the proximal surfaces of the scaphoid, the lunate and the triquetral bones. The three bones are united by interosseous ligaments which are flush with the articular cartilage of this surface. The articular cartilage on the radial surface is subdivided into a quadrangular medial and a triangular lateral portion. In the normal position of the hand, the scaphoid articulates with the lateral triangle, the lunate with the medial quadrangle and the articular disc and the triquetral with the medial part of the articular capsule. When the hand is deviated to the ulnar side, the triquetrum comes to lie oppos te the disc, the lunate opposite the medial quadrangle and the scaphoid opposite the lateral triangle.

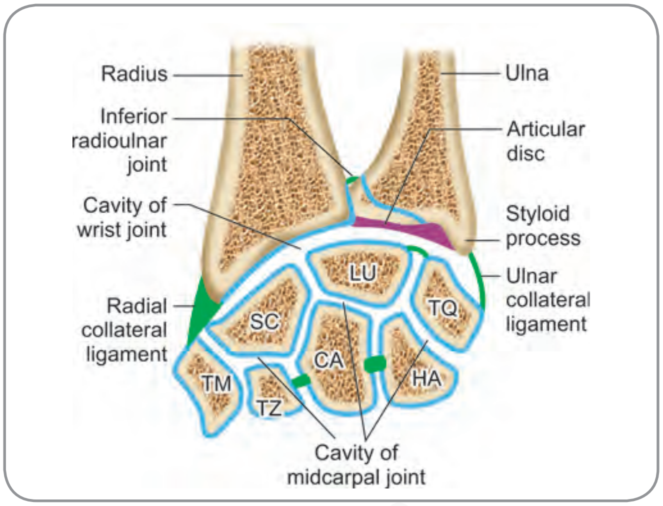


Fig. 18.13: Schematic coronal section through the wrist to show the formation of the articular surfaces of the inferior radioulnar, wrist and midcarpal joints. SC–Scapoid LU–Lunate, TQ–Triquetrum, TM–Trapezium, TZ–Trapezoid, CA–Capitate, HA–Hamate

Articular capsule: The ***articular capsule*** is attached to the margins of the proximal and distal articular surfaces. It is lined by synovial membrane. The anterior, medial and lateral parts of the capsule are thickened to form the ligaments of the joint.

Ligaments: The anterior part of the capsule has two thickenings which form the ***palmar ulnocarpal ligament*** and the ***palmar radiocarpal ligament***. The palmar ulnocarpal ligament extends downwards and laterally from the articular disc and the ulnar styloid to the proximal row of carpal bones. The palmar radiocarpal ligament extends downwards and medially from the distal end of radius to the proximal carpal row.

- The posterior part of the capsule is thickened in its lateral part to form the ***dorsal radiocarpal ligament***, which runs downwards and medially from the distal end of radius to the proximal carpal row.
- The strongest bonds of union are, however, the ulnar and radial collateral ligaments, which are thickenings of the capsule on the sides. The ***ulnar collateral ligament*** is attached proximally to the styloid process of the ulna and distally to the medial side of triquetrum and pisiform bones (Fig. 18.13). The ***radial collateral ligament*** is attached proximally to the styloid process of the radius and distally to the lateral side of the scaphoid bone. The radial collateral ligament is crossed by the radial artery. It is also crossed by the tendons of the abductor pollicis longus and the extensor pollicis brevis.

Blood Supply

The wrist joint is supplied by branches from various arteries present in its neighbourhood including the radial, u nar, and anterior interosseous arteries, and the deep palmar arch.

Nerve Supply

It is supplied by the anterior and posterior interosseous nerves. Dorsal and deep branches of the ulnar nerve may also send twigs to the joint.

Movements

The movements allowed at the wrist joint are those of flexion, extension, adduction and abduction.

Flexion at the wrist joint tends to bring the palm and forearm together. Straightening the wrist and fingers is called extension. Hyperextension is possible at the wrist.

Adduction and abduction are described with reference to the long axis of the forearm; lateral movement is abduction and medial movement is adduction. The radial styloid process extends further distally than the ulnar styloid process. This prevents abduction of the hand and so, range of adduction is greater than that of abduction.

Since the wrist is an ellipsoid, rotation is not possible. But, lack of rotation is compensated by supination–pronation of the forearm. However, circumduction as a combination of flexion, abduction, extension and adduction (or the reverse) is possible. Put together, circumduction and rotation of supination–pronation duplicate the movements of the shoulder, thus giving extensive mobility to the hand.

Similar movements take place at the joints between the proximal and distal rows of carpal bones (collectively called the ***midcarpal joint***) and add considerably to the range of the movements of the wrist (Fig. 18.14).

Since the carpal bones do not articulate with the ulna but only with the radius and the articular disc, the wrist is called the 'radiocarpal' joint and not the radio ulnocarpal joint.

OTHER JOINTS OF THE CARPUS

Intercarpal and Midcarpal Joints

The carpal bones, which are arranged in two rows, articulate with one another to form a compact mass. The presence of the midcarpal joint, which is between the proximal and the distal row makes it convenient to divide the intercarpal joints into joints of the proximal row and joints of the distal row.

Joints of the proximal row: In the proximal row, scaphoid, lunate and triquetrum are united by palmar, doral and interosseous intercarpal ligaments. The palmar ligaments connect the adjacent parts of the bones on their palmar aspect. The dorsal ligaments connect the bones on their dorsal aspect. The interosseous ligaments are short bands which connect contiguous sides of the bones.

Joints of the distal row: In the distal row, trapezium, trapezoid, capitate and hamate are similarly united by palmar, dorsal and interosseous intercarpal ligaments.

Joint of the pisiform: The pisiform bone sits on the palmar surface of the triquetrum and articulates with

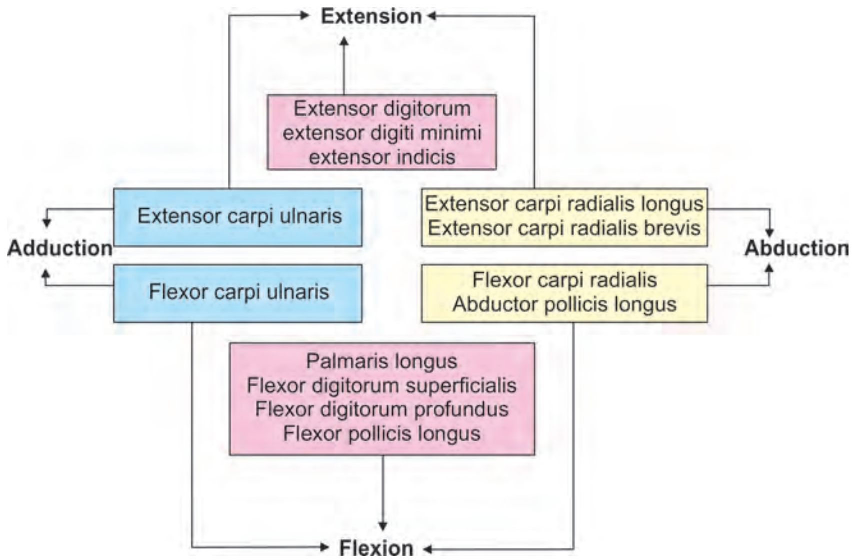


Fig. 18.14: Scheme to show the muscles respons ble for movements at the wrist joint

it by a small synovial joint. The pisometacarpal and the pisohamate ligaments connect the bone with base of the fifth metacarpal and the hook of the hamate respectively.

Midcarpal joint: The ***midcarpal joint*** (or the transverse intercarpal joint) is present between the proximal and distal row of carpal bones. It is an ellipsoid joint. The joint line is distally convex on the lateral side and distally concave on the medial side. The distal convexity on the lateral side is due to the prominent distal surface of the scaphoid to which the trapezium and the trapezoid articulate. The distal concavity on the medial side is formed by the medial surface of scaphoid, lunate and triquetrum. Capitate and hamate lie in this concavity. The fibrous capsule is thin and irregular. Some parts of the capsule are thickened and form the palmar and dorsal intercarpal ligaments. These pass between the proximal and distal row in irregular bands. The joint cavity of the midcarpal joint, which is lined by synovial membrane, is large. The central part of the cavity extends from side-to-side between the two rows of carpal bones. Extensions from this central portion run proximally between the three bones of the proximal row and distally between the four bones of the distal row. Deficiencies in one or more of the interosseous intercarpal ligaments may cause the joint cavity to communicate with the cavity of the wrist or with that of any of the carpometacarpal joints.

- ***Nerve supply:*** The anterior interosseous, the posterior interosseous, the dorsal branch of ulnar and the deep branch of ulnar nerves supply the joint.

MOVEMENTS AT THE RADIOCARPAL AND MIDCARPAL JOINTS

Movements between the carpal bones mainly occur at the midcarpal joint (Table 18.4); these, of course are in close association with the movements of the radiocarpal joints. It is, therefore, customary and convenient to consider them together.

Two important axes are involved—(1) the transverse axis and (2) the anteroposterior axis. Around the transverse axis, bending of the hand towards the front of forearm is flexion; bending towards the back of forearm is extension. Around the anteroposterior axis, deflecting the hand towards the medial side is adduction or ulnar deviation; deflecting towards the lateral side is abduction or radial deviation.

Some oblique movements are also possible. In addition, circumductory movements occur too. However, oblique and circumductory movements are associated with movements at the radioulnar and cubital articulations.

Table 18.4: Movements of carpal bones at the radiocarpal and midcarpal joints

Movement	Muscles producing
Flexion	Flexor carpi ulnaris, flexor carpi radialis, palmaris longus, abductor pollicis longus—assisted by flexor digitorum superficialis, flexor digitorum profundus, flexor pollicis longus
Extension	Extensor carpi ulnaris, extensor carpi radialis longus, extensor carpi radialis brevis—assisted by extensor digitorum, extensor digiti minimi, extensor indicis, extensor pollicis longus
Abduction	Extensor carpi radialis longus, extensor carpi radialis brevis, flexor carpi radialis, abductor pollicis longus—assisted by extensor pollicis longus
Adduction	Extensor carpi ulnaris, flexor carpi ulnaris

Added Information

- The carpus has an anterior concavity. This concavity is bridged by the flexor retinaculum. The retinaculum plays a major role in maintaining the carpal bones in position and so is considered an accessory ligament of the intercarpal and midcarpal joints.
- Flexion of hand, when fingers are extended, takes place mainly at the midcarpal joint though flexion otherwise occurs at both radiocarpal and midcarpal joints.
- During extension of hand, more movement occurs at the radiocarpal than the midcarpal joint.
- In both flexion and extension, the distal row of carpal bones rotate around the proximal row.
- Greater part of adduction of hand occurs at the radiocarpal joint and that of abduction at the midcarpal joint.
- When the fingers are in the grasping position, there is some extension at the wrist joint. This also is the position of natural comfort.
- Of the four muscles responsible for flexion, three are placed farther from the axis of the joint. This gives a mechanical advantage and so, flexion is more powerful than extension.

CARPOMETACARPAL JOINTS

Of the two carpometacarpal joints in the hand, only one is of importance, namely the first carpometacarpal joint. The bases of the medial four metacarpal bones form a common single carpometacarpal joint with the distal row of carpal bones (Fig. 18.15).

First Carpometacarpal Joint

The carpometacarpal joint of the thumb is a synovial joint of the saddle variety. It is formed between the trapezium and the first metacarpal bone.

Articular surfaces: The distal surface of the trapezium and the proximal surface of the first metacarpal articulate with each other to form this joint. The surface of the metacarpal is convex from side-to-side and concave from front-to-back. The surface on the trapezium shows reciprocal curvatures. Thus, this joint is a typical example of the saddle variety.

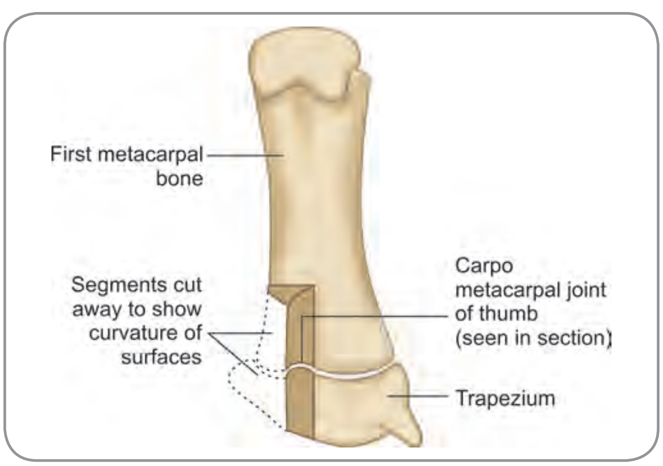


Fig. 18 5: Carpometacarpal joint of the thumb – sections of the metacarpal and of the trapezium have been cut away to show the anteroposterior curvatures of the articular surfaces of these bones – the parts cut away are shown in dotted line

Articular capsule: A strong fibrous capsule is attached to the ends of the articular surfaces of first metacarpal and trapezium. It is lined with synovial membrane.

Ligaments: The fibrous capsule is thickened on its deeper aspect to form three ligaments. The palmar and dorsal carpometacarpal ligaments connect the corresponding surfaces of the trapezium to the ulnar side of the base of the metacarpal. The radial carpometacarpal ligament is attached to the lateral sides of the trapezium and the first metacarpal bone.

Blood supply: The joint is supplied by radial artery and its first dorsal metacarpal branch

Nerve supply: Twigs from the posterior interosseus nerve and the superficial branch of the radial nerve supply the joint.

Movements

Since this is a saddle joint, movements can occur in two axes which are perpendicular to each other. Additionally, oblique movements, circumduction and rotational movements also occur.

The movements of the thumb are different from those of other digits of the hand because the thumb is rotated by 90° relative to the other digits. As a result, the first carpometacarpal joint is also placed at right angles to the common carpometacarpal joint and the plane of other digits. The dorsal surface of the thumb faces laterally (not posteriorly) and the palmar surface medially (not anteriorly). So, during flexion, the thumb moves medially in the plane of the palm; during extension it moves laterally in the same plane. In adduction, the thumb is carried backwards and in abduction, forwards. A special and specific movement occurring in this joint is 'opposition.' In full flexion, as the thumb moves across the palm, the first metacarpal bone undergoes a 30° rotation; the palmar aspect of the thumb is able to touch the palmar surfaces of the other digits. This movement is opposition. Similarly, in full extension, there is some amount of lateral rotation of the first metacarpal at the terminal stages of the movement.

Muscles producing movements (Fig. 18.16):

- ***Flexion:*** Flexor pollicis longus, flexor pollicis brevis, opponens pollicis
- ***Extension:*** Extensor pollicis longus and brevis
- ***Adduction:*** Adductor pollicis
- ***Abduction:*** Abductor pollicis longus and brevis
- ***Opposition:*** Opponens pollicis

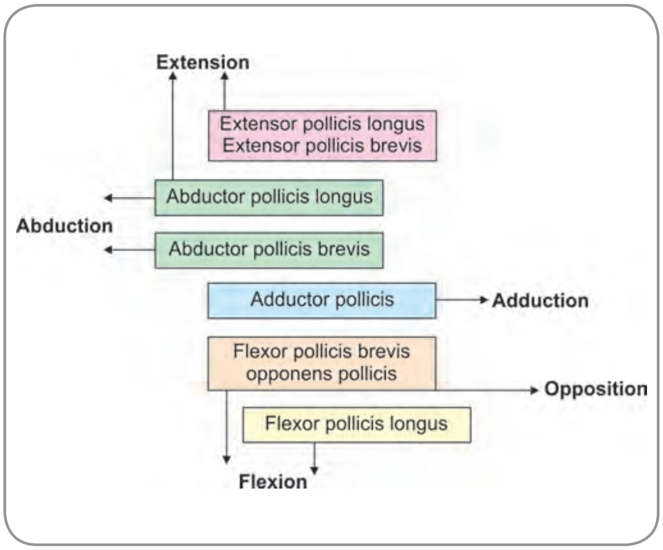


Fig. 18.16: Scheme to show the muscles responsible for movements at the carpometacarpal joint of the thumb; Note that flexion is associated with a certain amount of medial rotation, and extension with lateral rotation; Flexion, abduction, extension and adduction occuring in sequence constitute circumduction

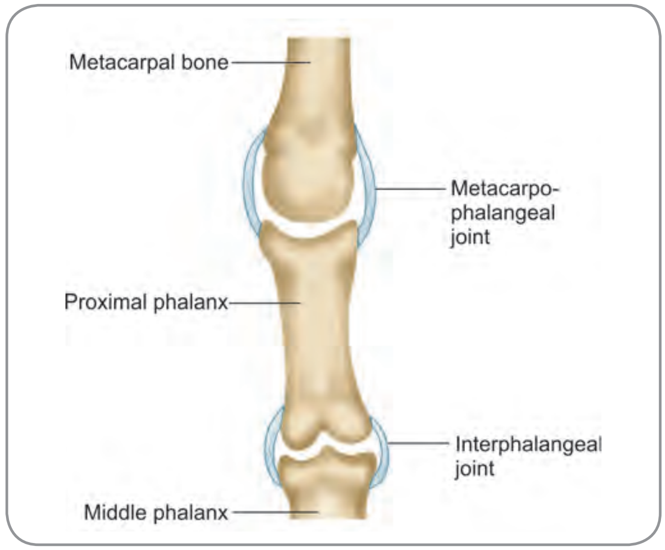


Fig. 18.17: Metacarpophalangeal and proximal interphalangeal joints

OTHER JOINTS OF HAND

The ***intercarpal***, common ***carpometacarpal***, and ***intermetacarpal*** joints are all plane joints and permit slight gliding movements. These movements confer considerable resilience to the region of the wrist. The ***metacarpophalangeal joints*** are typical ellipsoid joints allowing flexion, extension, abduction and adduction of the fingers. Rotation is not permitted. The ***interphalangeal joints*** are typical hinge joints of the condylar type. The thumb has only one such joint. Every other finger has two joints—proximal and distal. Movements at these joints are important in gripping and in all manipulative activity of the fingers (Fig. 18.17).

- Abduction and adduction of the digits take place at the metacarpophalangeal joints. They are described with reference to the long axis of the third digit. In abduction the index finger moves laterally, whereas the ring finger and the little finger move medially Movement of the third digit (middle finger) either medially or laterally is described as abduction (movement away from the imaginary midline of the middle finger). Abduction is produced by the dorsal interossei; abduction of the little finger is produced by abductor digiti minimi. The opposite movements of the digits are referred to as adduction (movement towards the imaginary midline of the middle finger).
- Flexion is the movement where the finger is bent in such a way to touch the palm. This movement occurs at the metacarpophalangeal and interphalangeal join s. At the metacarpophalangeal join (flexing the proximal phalanx), it is produced by lumbricals and interossei; at the proximal interphalangeal joint (flexing the middle phalanx), it is produced by flexor digitorum superficialis and flexor digitorum profundus; at the distal joint (flexing the distal phalanx) by profundus alone. Extension is the backward movement of fingers Similar to flexion, this movement also takes place at the metacarpophalangeal and interphalangeal joints. At the (distal and proximal) interphalangeal joints, it is produced by the extensor digitorum, lumbricals and interossei (predominantly the latter two). At the metacarpophalangeal joint, it is produced by the extensor digitorum; additionally, extensor indicis helps in extension of the index finger and the extensor digiti minimi in that of the little finger.

Added Information

- Three deep transverse metacarpal ligaments connect the palmar ligaments of the metacarpophalangeal joints of the medial four fingers. They unite the metacarpal heads and hence keep them as a single unit. This gives a unified framework to the hand and helps in the execution of skilled movements. Conversely, there is no deep transverse metacarpal ligament uniting the thumb and the index finger. This factor is again important because it helps in the increased mobility of the thumb.
- Adduction–abduction of the fingers can be done only when they are extended. In flexion of fingers, the base of the proximal phalanx is in contact with the anterior aspect of the metacarpal bone and the collateral ligaments of the metacarpophalangeal ligaments are taut. So, adduction-abduction cannot occur. In extension, the base of proximal phalanx is in contact with the head of the metacarpal and the ligaments are lax. So, adduction-abduction can occur.

Clinical Correlation

- Dislocation can take place at any of these joints but this is not common.
  - ***Scaphoid fracture:*** It is the most common carpal bone to get fractured as it crosses both the rows of carpal bones. When the fracture is at the waist of scaphoid, the proximal one-third of scaphoid is likely to undergo avascular necrosis as the bone's blood supply usually is by a branch of the radial artery and this branch enters the bone on its distal aspect and proceeds to the proximal portion.
  - ***Bennett's fracture:*** It is the fracture dislocation of the palmar base of the first metacarpal bone with either sub-luxation or dislocation of the first carpometacarpal joint.
- The pincer mechanism of the thumb is the most important feature of the hand; it is brought about by the ability of the thumb to oppose other fingers. But tactile sensations of the opposing skin surfaces are essential for the pincer action to 'really' get executed.
- Immobiliation of the hand when required, should be done in the ***position of function***

HAND AS A SPECIALISED UNIT OF FUNCTION

The upper limb is well specialised for extreme range of movements. In addition, it also has the most prehensile hand at the distal end. The pincer action of the thumb (ability to grasp an object between the thumb and the index finger) is an added advantage

All these actions are put to the best advantage in anatomical adaptations. The most comfortable working position of the hand is when with the forearm in mid prone position, the wrist is partially extended. The forearm is the most stable in the midprone position. When the wrist is in partial extension, the flexors and the extensors of the fingers function with maximal advantage; the flexors and the extensors of the wrist fix the joint in stability. Thus, both stability and mobility are obtained.

Computing the combination of movements, the position of rest and the position of function for the hand have been described.

- ***Position of rest:*** Semiprone, wrist extended, all fingers except index in flexion, thumb extended;
- ***Position of function:*** Semiprone, wrist extended, all fingers flexed, thumb and index in opposition.

MOVEMENTS OF FINGERS

The fingers are capable of highly intricate and refined movements It can well be correlated that the movements of fingers have been largely responsible for the advanced civilisation of mankind. Flexion of the fingers in association with variable combinations of adduct on-abduction and opposition of fingers and of extension-hyperextension of the wrist produces efficient and powerful positions of the hand. A few such positions are:

- ***Flexed fingers:*** Each finger can be flexed at the metacarpophalangeal and interphalangeal joints, one at a time; or they can all be flexed together While flexing individually, it can be seen that the pad of the flexed finger touches almost the same spot on the palm (usually on the thenar eminence). When they are flexed together, a crowding, especially of the 2nd and the 4th giving little room for the middle finger, can be seen. Thus, it can be stated that flexed fingers are adducted fingers. When flexed and adducted the fingers steady one another.
- ***Making fist:*** This position is achieved by flexion at metacarpophalangeal and interphalangeal joints of all fingers including the thumb. Long flexor muscles of the thumb and digits contract. The movement is complemented by extension at the wrist. 'Fist' is powerful only when there is extension at the wrist, which is brought about by the extensor carpi ulnaris and radialis muscles.
- ***Cupping hand:*** This position is when the palm is made into a deep concavity. There is flexion at the metacarpophalangeal and interphalangeal joints of all the fingers including the thumb. However, the position is marked by abduction and opposition of the thumb; such movements of the thumb also draw the thenar eminence forward producing the lateral part of the concavity To complement this, the fourth and the fifth metacarpals also undergo some amount of rotation at their respective metacarpophalangeal joints; this draws the hypothenar eminence forward producing the medial part of the concavity. To increase the concavity further, the palmaris brevis muscle contracts. So the skin over the hypothenar eminence is puckered leading to better gripping. The position can be achieved with both adduction and abduction of fingers. When the fingers are adducted, the cup of the palm is prominent. However, when a rounded or spheroidal object is gripped by the hand, the fingers move into abduction around the object, still maintaining most of the concavity.
- ***Making a power grip:*** This position, otherwise called the power grip or the palm grasp, is when the fingers flex and make a firm and powerful hold against the palm. Imagine to hold a metal rod tightly. The medial four fingers wrap around the rod and impinge on the palm. The thumb gives pressure from the opposite side and retains the rod. Since the object is grasped by the palm, it is called the palm grasp. Flexion at the interphalangeal joints by the long flexors, flexion at the metacarpophalangeal joints by the small muscles of hand and extension at the radiocarpal joint are responsible for this position. The grip is more powerful with little extra extension at the wrist; flexion of wrist reduces the 'power' of the power grip.

- ***Making a finger grip:*** This is the position when the medial four fingers are involved in holding or lifting an object without pressure from the thumb. Imagine to hold a suitcase. The four fingers grip the handle of the case; thumb is relatively free. The four fingers are also not tightly wrapped around the handle, thus causing less strenuous contraction of the muscles concerned. This position consumes less energy and can be held for longer duration.
- ***Writing position:*** This is the position where there is extension at the wrist, flexion at the metacarpophalangeal joints and a combination of flexion and extension at the interphalangeal joints. The position is brought into action while holding a pen, while performing refined, intricate movements of the fingers and while making precision activities. Though it is customary to describe the position as 'flexion at metacarophalangeal and extension at interphalangeal' joints, varying° of flexion-extension occur at the interphalangeal joints depending on the immediate necessity.

Multiple Choice Questions

1. The syndesmosis connecting clavicle to scapula is:
   a Coracoclavicular ligament
   b. Coracoacromial ligament
   c. Acromioclavicular ligament
   d. Coracohumeral ligament

2. Protraction–retraction of scapula occur at:
   a. Scapulothoracic joint
   b. Acromioclavicular joint
   c. Glenohumeral joint
   d. Shoulder girdle

3. The ligament of shoulder joint that has no direct connection to the joint structures is:
   a. Coracoacromial ligament
   b. Coracohumeral ligament
   c. Transverse humeral ligament
   d Glenoidal labrum

4 The inferior aspect of shoulder joint capsule is supported during abduction by:
   a. Triceps and teres major
   b. Triceps and teres minor
   c. Latissimus dorsi and teres major
   d. Latissimus dorsi and triceps

5. With regard to plane of scapula:
   a. It is perpendicular to the sagittal plane of the body
   b. Movements in this plane twist the joint capsule
   c. Rotator cuff muscles act in this plane
   d. It is perpendicular to the coronal plane of the joint

6. Alert ligaments of the shoulder are:
   a. Glenohumeral ligaments
   b. Rotator cuff muscles
   c. Glenoidal labrum and transverse humeral ligament
   d. All accessory ligaments of the joint

7. The cavity of inferior radioulnar joint is:
   a. Vertical
   b. L-shaped
   c. T-shaped
   d. Horizontal

8. The axis of pronation–supination moves:
   a. Laterally in pronation
   b. Laterally in supination
   c. Medially in pronation
   d. Posteromedially in pronation

9. The distal articular surface of the wrist joint is formed by
   a. Scaphoid lunate and triquetral
   b. Scaphoid, lunate and pisiform
   c. Lunate, triquetral and pisiform
   d Scaphoid, triquetral and pisiform

10. Carpometacarpal joint of thumb:
   a. Is between trapezium and first metacarpal bone
   b. Is of ellipsoidal variety
   c. Is continuous with the carpometacarpal joint of the index finger
   d. Has no movement of circumduction

ANSWERS

1 a **2.** a **3.** a **4.** a **5.** c **6.** b **7.** b **8.** a **9.** a **10.** a

Clinical Problem-solving

Case Study 1: A man was playing with his 6-year-old daughter. Suddenly, as a vehicle passed by, he lifted the child from the kerb by pulling her upper limbs. Within few minutes, the child started writhing in pain and pointed to her left forearm?
- What do you think should have happened?
- What is the reason for such a condition to occur?
- How would you evaluate the prognosis in this condition? Will the child suffer from any permanent disability?

Case Study 2: A small boy had fallen down and had injured the interphalangeal joints of his ring finger. The next day when he was trying to hold on to his cricket ball, he found he could not do so; apart from the pain, the grip was also very loose.
- What is the probable reason for the looseness of the grip?
- Which small muscle contributes actively to cupping of hand?
- Apart from joint movements, what two other factors add to the cupping mechanism?

(For solutions see Appendix).

Chapter 19

Nerves of Upper Limb

Frequently Asked Questions

- Write a note on the supraclavicular nerves.
- Write notes on a) Prefixation of brachial plexus, (b) Axial lines of upper limb.
- Substantiate for the dual nerve supply to some muscles of the upper limb.

The structures of the upper limb are predominantly supplied by the nerves of the brachial plexus (Greek. brachyo=arm). Some of the structures which are encountered in our study of the upper limb are supplied by branches from the cervical plexus. A detailed study of the cervical plexus will be taken up when we study the head and neck. Only those branches of the cervical plexus which supply the upper limb structures are discussed here. Brachial plexus and its branches are discussed in detail in the chapter on axilla. Additional information with regard to its pattern of distribution is studied in this chapter

- ***Supraclavicular nerves***: The superficial branches of the cervical plexus are in two groups: (1) ascending and (2) descending. The descending superficial branches are otherwise called the ***supraclavicular nerves***. The third and the fourth cervical spinal nerves give out a root each. Both these roots join together to form a trunk of considerable thickness. This trunk passes under cover of sternocleidomastoid and emerges from under cover of the muscle's posterior border in the middle of the neck. As it crosses the inferior part of the neck obliquely down, it divides into three radiating branches—(1) the medial, (2) intermediate and (3) lateral branches. These branches pierce the deep fascia of the inferior aspect of the neck and reach the superficial aspect. The medial braches are the smallest of the lot. They supply the skin and fascia of the lower neck and upper chest till the level of the angle of sternum. Twigs are given to the sternoclavicular joint too. The intermediate set of branches pass over the clavicle (but deep to platysma) and supply the lower neck and upper chest till the level of the third rib. These branches may groove or pierce the clavicle. The lateral branches pass over the lateral part of clavicle and supply the chest and shoulder till the level of the distal aspect of deltoid muscle. They also supply the acromioclavicular joint.
- ***Muscular branches from cervical plexus*** (encountered in the upper limb): The branches of the cervical plexus are classified as superficial and deep. The deep branches are further sub-classified as the lateral and medial branches. In the lateral group are the muscular branches to the Sternocleidomastoid, trapezius and levator scapulae. The branch to sternocleidomastoid is from the C2 nerve; it enters the muscle on its deep surface and supplies. The branches to trapezius are from C3 and C4 nerves; they emerge on the posterior border of sternocleidomastoid, run posteriorly and enter the trapezius on its anterior border or under surface. Two branches go to the levator scapulae muscle; they arise from C3 and C4 nerves and enter the lateral surface of the muscle.

BRACHIAL PLEXUS

The brachial plexus is discussed in detail in the chapter on axilla. However, additional information on important points with regard to its clinical and applicative anatomy are given here (Fig. 19.1).

Constitution and formation of brachial plexus: It is already learnt that the brachial plexus passes through a series of stages before the nerves of distribution emerge out. Four such stages can be recognized as:

1. Undivided ventral rami forming the 'root' stage;
2. Formation of the three trunks;

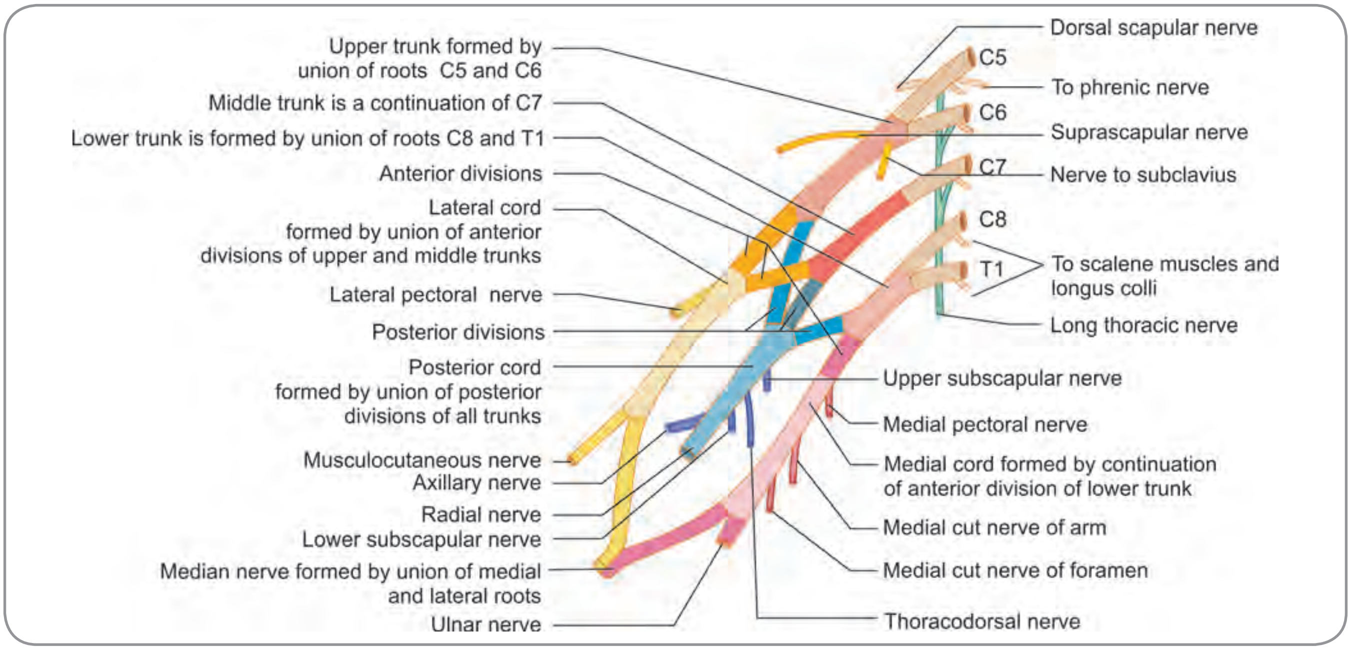
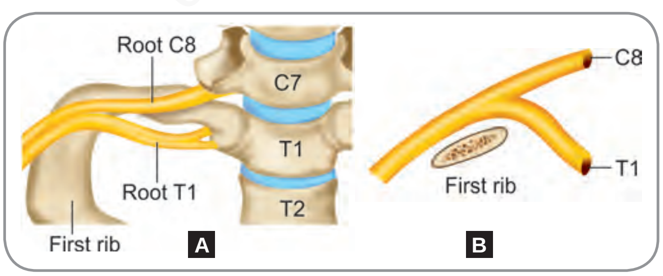


Fig. 19.1: Scheme to show the formation and branches of the brachial plexus

3. Each trunk dividing into the anterior and the posterior divisions and
4. Union of the divisions to form the cords from which arise the nerves of distribution.

- ***Roots of the plexus:*** These are the undivided ventral rami forming the plexus; they have a very short independent course in the neck (Figs 19.2 and 19.3).
- ***Trunks:*** These are three in number and have a sequential order from above downwards. The fifth and sixth cervical ventral rami form the upper trunk, the seventh ramus alone forms the middle trunk and the eighth cervical and first thoracic rami form the lower trunk. The lower trunk usually grooves the first rib and is in close contact with it.



Figs 19.2A and B: Relation of root T1 of brachial plexus to the first rib

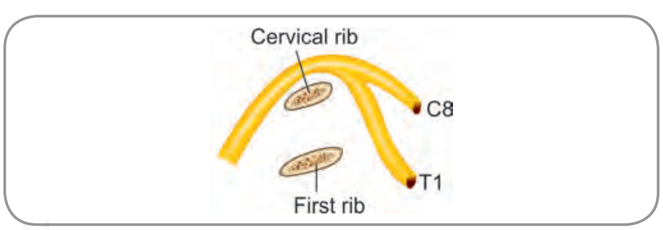
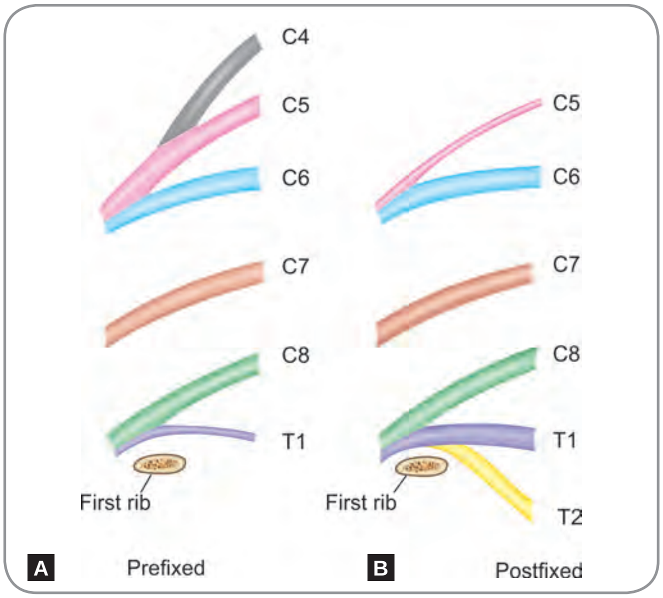


Fig. 19.3: Relation of root T1 of brachial plexus to a cervical rib

- ***Divisions:*** Each of the trunks divides into an anterior and a posterior division This stage has morphological significance. The anterior and posterior divisions signify the nerve fibres destined to supply the embryological ventral (flexor) and embryological dorsal (extensor) parts of the limb respectively.
- ***Cords:*** These are three in number and are in close relation to the axillary artery. The lateral cord which lies lateral to the artery is formed of the union of the anterior divisions of the upper and middle trunks (and so the anterior parts of the fifth, sixth and seventh cervical spinal nerves). The medial cord that lies medial to the artery is formed by the anterior division of the lower trunk (and so, has the anterior parts of the eighth cervical and first thoracic spinal nerves). The posterior cord that lies posterior to the artery is formed of the union of all the posterior divisions of all the three trunks (and so, has the posterior parts of the fifth, sixth, seventh and eighth cervical nerves and the first thoracic nerve).

Regarding the nerves of distribution, it should be remembered that though derived from a cord, any given nerve need not have fibres from all the constituent spinal nerves of the cord. A typical example is the axillary nerve. This nerve is derived from the posterior cord (constituents of which—all posterior divisions of all three trunks); but the axillary nerve has fibres from fifth and sixth cervical nerves only.

Prefixation or ***postfixation*** (Figs 19.4A and B) of the plexus may occur. The presence of a cervical rib need not coincide with a corresponding shift in the fixation of the plexus.



Figs 19.4A and B: Some variations in the origin of the brachial plexus

Pattern of innervation to the skin and muscles of the upper limb: There are several noteworthy points to be observed, analysed and studied with regard to the pattern of innervation to the skin and muscles of the limb. These include:

- Each nerve of distribution in the upper limb is composed of fibres from more than one spinal nerve.
- Pattern of distribution to the skin and to the muscles is not identical.
- The skin of the limb is drawn from the covering of adjacent parts of the trunk. As a limb bud grows longer and longer, the 'original' skin covering the bud is carried to the distal parts of the limb. The proximal parts, especially those near the root of the limb, draw their covering from adjacent parts of the trunk The nerve supply to such portion of skin will also be drawn from the areas which contributed the skin Thus, in the cutaneous innervation of the limb, some portions of skin may be supplied by nerves wh ch have no role in the supply of the deeper lying structures or muscles.
- Among the muscles, some have undergone fusion, some have migrated to different locations and some may have become vestigial. However, the 'original' nerve supply is retained and the developmental factor of the muscle can be deduced from its innervations.
- The upper limb is supplied by the brachial plexus. The central nerves of the plexus remain buried deep in the substance of the limb; they (or their branches) come to the surface only in the periphery of the limb.
- If two spots of skin are considered, that spot nearer the preaxial border is supplied by a higher nerve (nerve of the higher spinal segment) and that nearer the postaxial border is supplied by the lower (nerve of the lower spinal segment) nerve.
- If two skin spots within the preaxial area are considered, the higher spot will be supplied by the higher nerve and the lower by the lower nerve.
- If two skin spots within the postaxial area are considered, the higher spot will be supplied by the lower nerve and the lower by the higher nerve.
- The limb muscles do not receive any supply from the dorsal rami of spinal nerves.
- The dorsal and ventral groups of muscles are supplied by the dorsal and ventral divisions of the ventral rami respectively.
- The ventral muscle group is always more extensive than the dorsal group and so the ventral nerves are more in number. The spinal nerves supplying the dorsal group are C5, C6, C7 and C8 (less in number) and those supplying the ventral group are C5, C6 C7, C8 and T1 more in number).
- If the dorsal group nerves and the ventral group nerves are compared, the additional nerve is postaxial.
- Of two muscles in the limb, that nearer the head end of the body is supplied by the higher nerve and that nearer the tail end is supplied by the lower nerve.

Muscles with Dual Nerve Supply

If a muscle is supplied by more than one nerve, it indicates that the muscle is derived from more than one element. Muscle tissue derived from the originally separate elements (supplied separately by the corresponding separate nerves early in development) has fused; as a result, a single muscle is supplied by more nerves.

Such fused elements can be from the same group (ventral flexor or dorsal extensor) or from different groups.

The examples for fusion of elements from the same group are the pectoralis major and the flexor digitorum profundus. The pectoralis major is supplied by the lateral and medial pectoral nerves. The lateral pectoral nerve is a branch of the lateral cord (anterior divisions of C5, C6 and C7). The med al pectoral nerve is a branch of the medial cord (anterior divisions of C8 and T1). The muscle, therefore, is a fusion of muscle tissue derived from separate elements of the same ventral group. The lateral part of the flexor digitorum profundus is supplied by branches of the median nerve (C7, C8 and T1) and the medial part by branches of ulnar nerve (C8 and T1). This again is a result of fusion of derivatives from the elements of the ventral group.

No typical example for fusion of elements from both the groups is seen in the upper limb The brachialis may receive fibres from the musculocutaneous (lateral cord, anterior divisions of usually C5 and C6 with C7 also sometimes) and radial nerves (posterior cord, posterior divisions of C5, C6, C7, C8 and T1). However, the fibres from the radial nerve innervating the muscle seem to be afferent and not motor.

Axial Lines of the Upper Limb

These are lines marked on the surface, indicating a break in the numerical sequence of skin innervation. We have already seen that the central nerves of the brachial plexus run deep in the limb and reach the skin only in the periphery. However, due to developmental factors, some of them do not reach the skin surface and then are replaced by cutaneous branches by the neighbouring nerves Cutaneous representation from some spinal nerves is therefore missing. This shows out as gaps or 'jumps' in the sequence of numbers of the spinal nerves supplying the skin of the limb. If the dermatomes of the arm are marked out, it can be seen that the lateral aspect is supplied by fibres of C4 and C5. The medial aspect is supplied by T2 and T1. C6,C7 and C8 do not feature in the arm. Therefore, a hiatus is created. This hiatus is called the ***axial line***.

The dorsal axial line starts on the median line of the back opposite the C7 vertebra, runs laterally and turns into the posterior aspect of the arm; it extends till the level of the elbow. The ventral axial line is more extensive. It starts at the manubriosternal joint, extends laterally across the chest, runs down along the midline of the front of arm and reaches the upper third of the forearm.

Multiple Choice Questions

1. Supraclavicular nerves are the:
   a. Ascending superficial branches of cervical plexus
   b. Ascending deep branches of cervical plexus
   c. Descending superficial branches of cervical plexus
   d. Descending deep branches of cervical plexus

2. The anterior and posterior divisions of the trunks of brachial plexus indicate:
   a. Embryological ventral and dorsal parts
   b. Embryologic splanchnic and somatic parts
   c. Embryologic mesodermal and ectodermal parts
   d. Embryologic comic and extracoelomic parts

3. With regard to the pattern of muscular innervation, the ventral nerves are more in number because"
   a. The ventral muscle mass is more extensive
   b. The ventral muscle mass is less powerful
   c. The ventral muscle mass is more accurate
   d. The ventral muscle mass is more inert

4. An axial line indicates:
   a. Break in the numerical sequence of dermal innervation
   b. Break in the numerical sequence of muscular innervation
   c. Break in the functional sequence of vasomotor innervation
   d. Break in the functional sequence of dermomuscular innervation

5. The 'root' stage of the brachial plexus is formed by:
   a. The undivided spinal nerves
   b. The undivided dorsal rami
   c. The undivided ventral rami
   d. The undivided trunks

ANSWERS

1. c **2.** a **3.** a **4.** a **5.** c

Clinical Problem-solving

Case Study 1: A 23-year-old young man was diagnosed of having a cervical rib on the left side.

- What would be the 'fixation' of his brachial plexus on the left side and what will be the relation of the plexus to the cervical rib?
- In what way will his axial lines be altered/not altered with relation to the cervical rib?
- Correlate the effects of 'fixation' of the brachial plexus and the presence of a cervical rib in an otherwise normal individual.

(For solutions see Appendix).

Chapter 20

Cross-Sectional, Radiological and Surface Anatomy of Upper Limb

Frequently Asked Questions

- Draw a neat labeled diagram of the transverse section of the wrist.
- Write notes on: (a) Importance of epiphyseal fusion, (b) Role of X-rays in determination of age, (c) Surface marking of axillary artery.
- Give the surface marking of the following: (a) Superficial palmar arch, (b) Median nerve in the forearm, (c) Radial nerve in the arm, (d) Flexor retinaculum, (e) metacarpophalangeal joint of forefinger.

CROSS-SECTIONAL ANATOMY OF THE UPPER LIMB

The upper limb can be considered an organ of force and function. It consists of several muscles which are grouped into the functional flexor and extensor compartments. Due to muscular attachments at various levels, cross-sections at different levels show different pictures.

The cross-sectional pattern of the upper limb can be studied in three sections of the arm, one section of the elbow joint, two sections of the forearm and one section of the wrist.

- ***Transverse section of arm at the level of the junction of proximal and middle thirds (upper arm section)*** (Fig. 20.1):

  This section passes through the main muscles of the arm and therefore, appears bulky. The muscles clothe the humerus on all sides.

  The humerus itself appears more or less triangular in section; the bone is covered by a bulk of muscles of the lateral and posterior aspects. The deltoid covers it

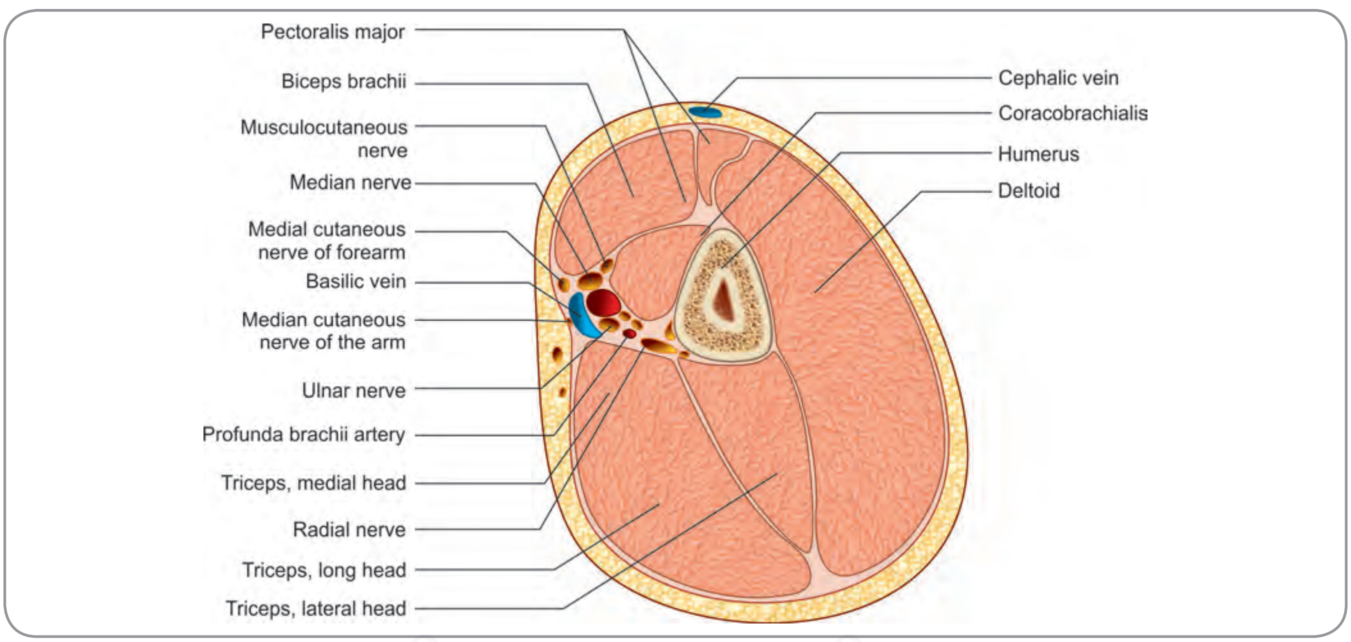


Fig. 20.1: Transverse section of arm at the level of the junction of proximal and middle thirds (upper arm section)

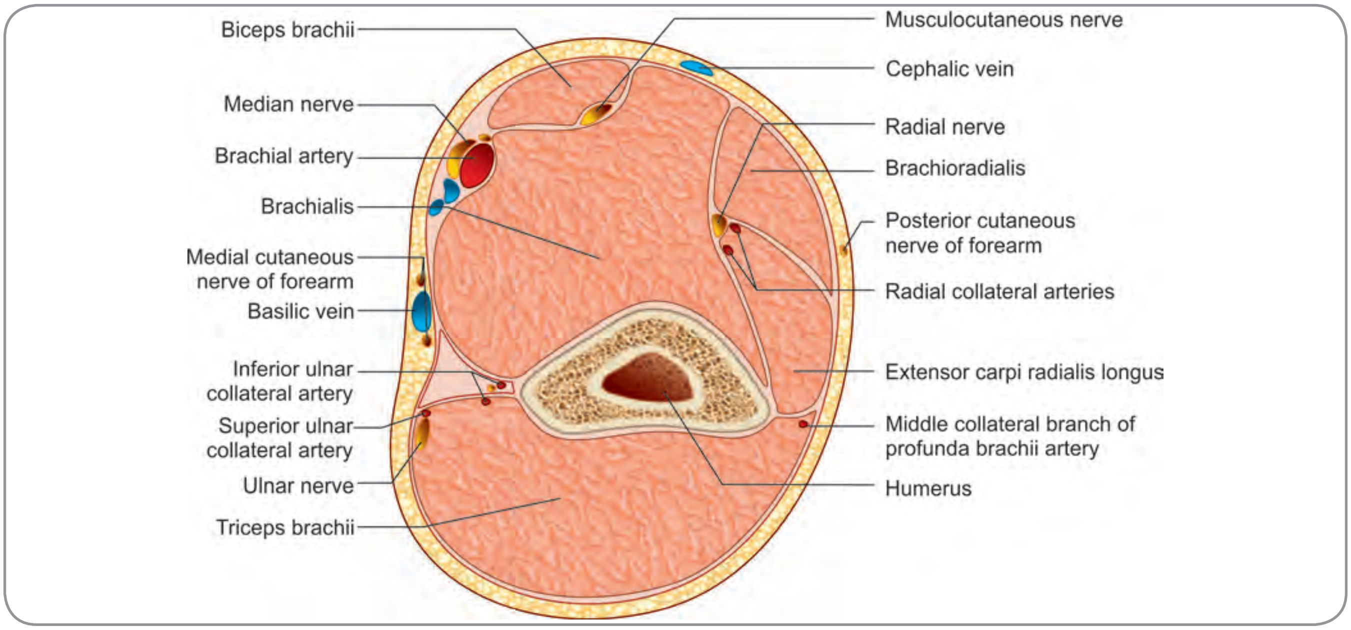


Fig. 20.2: Transverse section of arm at the middle of its length (mid arm section)

on the lateral aspect and the three heads of triceps cover it on the posterior aspect. Closely approximated to the anteromedial slope of the bone (the area of the bone between the two lips of the bicipital groove but distal to the attachment of latissimus dorsi, seen as a slope at this level of section) is the coracobachialis. Biceps brachii lies superficial to the coracobrachialis on the anteromedial aspect. The tendon of the long head of biceps can be seen sandwiched between the biceps and the coracobrachialis. Occupying a shallow gutter between the rounded margins of deltoid and biceps on their superficial aspects is the pectoralis major, whose fibres can be seen to join the lateral lip of the bicipital groove.

The medial intermuscular septum is seen as a thick partition extending from the medial lip of bicipital groove and the deep fascia on the medial aspect of the arm. Embedded in the connective tissue anterior to the medial septum, lies the brachial artery with its venae comitantes and with the median nerve lying anterior and the ulnar nerve lying posterior to it. The profunda brachii artery which had arisen from the brachial artery a little proximal to this level, can be located posterolateral to the brachial artery and anterior to the medial head of triceps. The musculocutaneous nerve is lateral to the median nerve and between the biceps and the corcaobrachialis. The medial cutaneous nerve of forearm is medial to the median nerve. The radial nerve is seen in the posterior compartment, lying lateral to the profunda brachii artery and anterior to the medial head of triceps.

The basilic vein can well be made out on the medial aspect, lying superficial to the brachial artery The cephalic vein is in the superficial plane on the anterior aspect of the arm.

- ***Transverse section of arm at the middle of its length (mid arm section)*** (Fig. 20 2): This section shows the muscles better compacted around the humerus.

The bone is more or less circular in section. The medial and the lateral intermuscular septa can be well made out; the medial septum is thicker and marked. The septa extend from the corresponding aspects of the humerus to the respective sides of the arm, thus separating the anterior and posterior compartments of the arm. The brachialis muscle wraps around the bone on the medial, anterior and lateral aspects and attaches to both the intermuscular septa. The biceps brachii is anteromedial to the brachialis and overhangs the medial aspect of the arm. Lying between the brachialis and the biceps is the musculocutaneous nerve.

The brachial artery and its venae comitantes, along with the median nerve and the basilica vein are seen on the medial aspect of the arm, lying within the connective tissue on the anterior aspect of the medial septum.

The three heads of triceps are clearly demarcated in the posterior compartment. The radial nerve occupies a position behind the lateral septum close to the humerus (where it is traversing the radial groove) The profunda brachii vessels accompany the radial nerve. The ulnar nerve has pierced the medial septum and has reached the posterior compartment at this level It can be located on the medial aspect of the arm, behind the medial septum; it is accompanied by the superior ulnar collateral vessels. The medial cutaneous nerve of forearm lies in the superficial plane on the medial aspect of arm; similarly, the cephalic vein can be seen in the superficial plane on the anterior aspect of the arm.

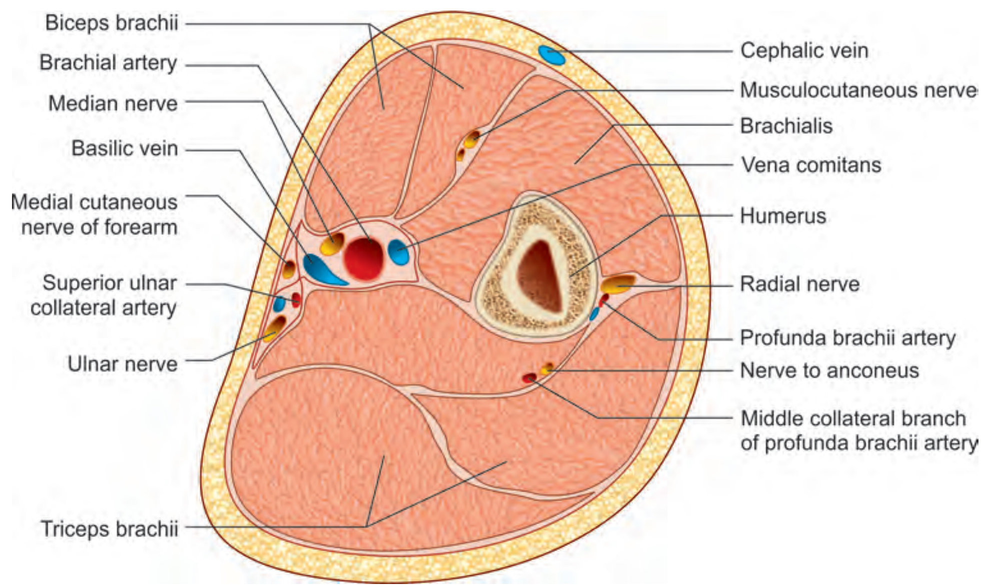


Fig. 20.3: Transverse section of arm about 2 cm above the medial epicondyle (distal arm section)

- ***Transverse section of arm about 2 cm above the medial epicondyle (distal arm section)*** (Fig 20.3): This section shows the lower part of humerus which is anteroposteriorly flattened with an anterior convexity. The medial and lateral supracondylar ridges are well marked on the medial and lateral aspects respectively; the medial intermuscular septum is clearly defined.

Some of the forearm muscles have originated proximal to this level and therefore, can be seen.

The brachialis envelopes the humerus from the anterior aspect. Anterior to the brachialis, the biceps brachii can be seen to be occupying a muscular groove of the former. Between the two muscles is the musculocutaneous nerve. The lateral aspect of brachialis is carved out to accommodate two muscles of forearm, namely, the brachioradialis (anteriorly) and extensor carpi radialis longus (posteriorly and still attached to the lateral supracondylar ridge). The lateral intermuscular septum is very thin and is in the plane between the brachialis and the forearm muscles. The radial nerve, which is a nerve of the posterior compartment, is seen lateral to the septum and in the gap between the three muscles (brachialis, brachioradialis and extensor carpi radialis longus). Twigs of radial collateral arteries can also be seen near the radial nerve. The brachial artery is on the anteromedial aspect of the arm lying immediately beneath the deep fascia It is accompanied by its venae comitantes; the median nerve lies anteromedial (or anterior) to the artery.

The basilic vein is seen lying in the superficial plane on the medial aspect of the arm. The cephalic vein lies in the superficial plane on the anterior aspect.

The posterior aspect of humerus appears more or less flat; the triceps brachii muscle is closely approximated to the bone and forms the bulk of the posterior compartment. The ulnar nerve can be located on the medial aspect of the triceps. Branches of superior and inferior ulnar collateral arteries can be seen near the medial intermuscular septum.

If keenly observed, the medial cutaneous nerve of forearm can be located in the superficial plane near the basilica vein. Similarly, the posterior cutaneous nerve of forearm can be made out in the superficial plane on the lateral aspect of the arm.

Significance of the level: It can be noticed that the forearm muscles have made their appearance at this level. The extensors of the forearm (though not the flexors) can be seen on the lateral aspect. The lateral intermuscular septum thus is not strictly lateral but has been pushed anteriorward.

- ***Transverse section at the level of the elbow joint:*** Through this section cuts through the elbow joint, the muscles seen are the forearm muscles.

The elbow joint is transected and the radius and ulna are seen. The olecranon of the ulna is cut; the coronoid process of ulna and the head of radius are made out. The entire section is more or less triangular with the base of the triangle on the posterior aspect.

An imaginary oblique line extending from the olecranon to the anterolateral aspect of the section and passing through the joint, can be considered as the dividing line between the flexor and the extensor compartments.

Anterior to the imaginary line is the flexor compartment. The brachialis muscle is seen anterior to the olecranon

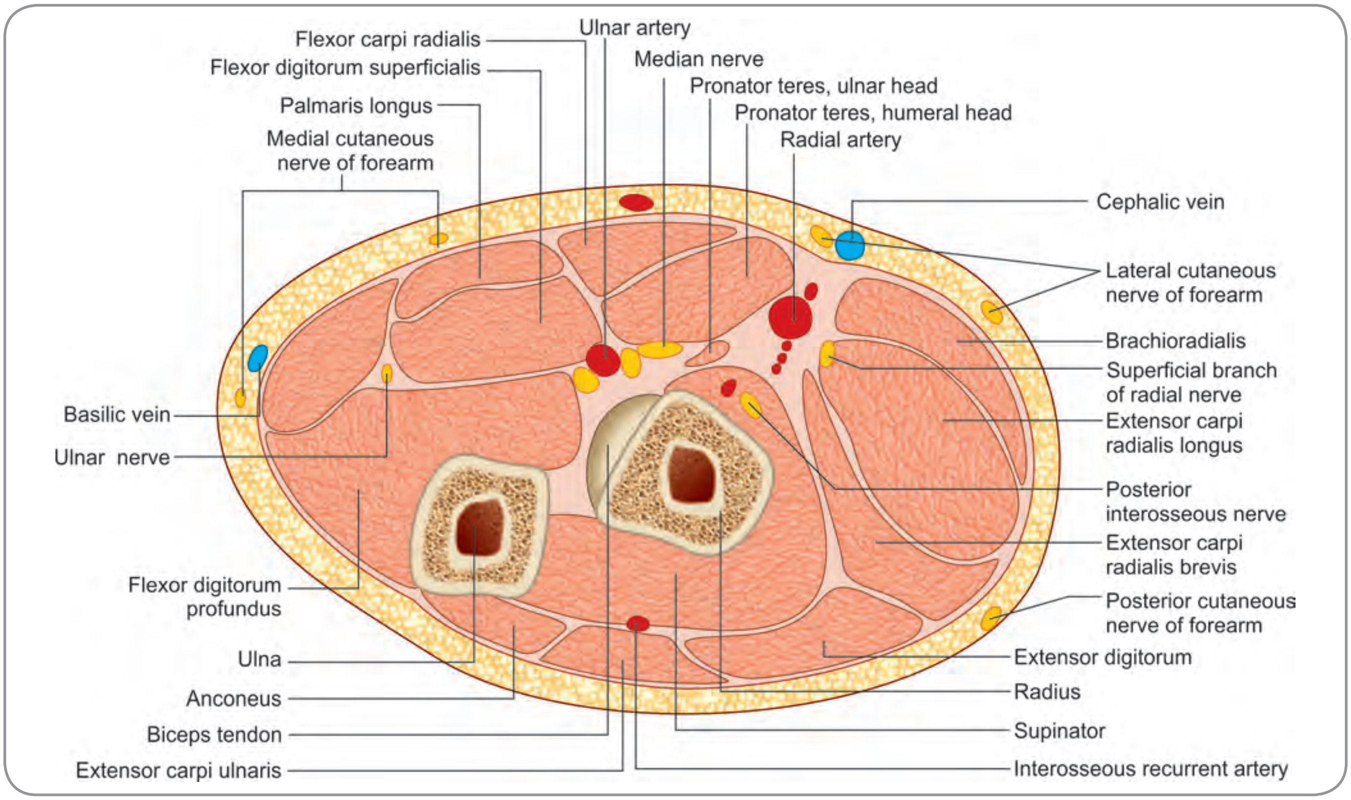


Fig. 20.4: Transverse section of the forearm at the level of the radial tuberosity (proximal forearm section)

and head of radius. Lying close to brachialis, is the tendon of biceps. When the entire section is viewed, both the brachialis and biceps appear to be anterolateral and not 'entirely' anterior. Spread across the anterior aspect are the superficial muscles of the forearm. The flexor carpi ulnaris muscle is seen on the medial aspect. The ulnar nerve lies deep to the flexor carpi ulnaris, that is, between the muscle and the elbow joint The median nerve is seen between the superficial flexors and the brachialis. Very closely on the lateral side of the median nerve, the two terminal divisions of the brachial artery, namely, the ulnar and radial arteries are seen. Of the two, the ulnar artery is medial and the radial artery lateral. Lying in the groove between the brachioradialis and the extensor carpi radialis longus on their medial aspect (and thus, posterior to the ulnar and radial arteries) are the radial and posterior interosseous nerves.

A small section of anconeus muscle may be seen posterior to the ulna.

The medial cutaneous nerve of forearm occupies the superficial plane on the anterior aspect of the section and the lateral cutaneous nerve of forearm occupies the superficial plane on the lateral aspect of the section.

- ***Transverse section of the forearm at the level of the radial tuberosity (proximal forearm section)*** (Fig. 20 4): This section shows the two bones of the forearm and the two muscular compartments. The sections of the two bones appear quadrangular. The deep fascia of the forearm (antebrachial fascia) is attached to the posterior aspect of ulna. If an oblique line is extended from this point of attachment to the anterolateral aspect of forearm, it would serve as the division plane between the flexor and extensor compartments of the forearm. It can clearly be seen that the flexor compartment is anteromedial and the extensor compartment is posterolateral.

The flexor digitorum profundus muscle is closely approximated to the anterior aspect of the ulna. Dipping in between the two bones and closely related to the anteromedial aspect of the radius is the biceps tendon. Lying in the anterior compartment, from medial to lateral are the flexor carpi ulnaris, the flexor digitorum superficialis, the palmaris longus, the flexor carpi radialis and the pronator teres. The muscles may be so 'bunched' that the palmaris longus may be superficial to the flexor digitorum superficialis and the flexor carpi radialis superficial to the pronator teres.

Our attention may now be shifted to the imaginary oblique line that was drafted out. This line cleaves through a neurovascular plane. Lying anterior to the radius bone and biceps tendon are the median nerve and the ulnar artery (medial to the nerve). Very often, the two heads of the pronator teres can be distinctly made out at this level and the median nerve can be seen to be sandwiched

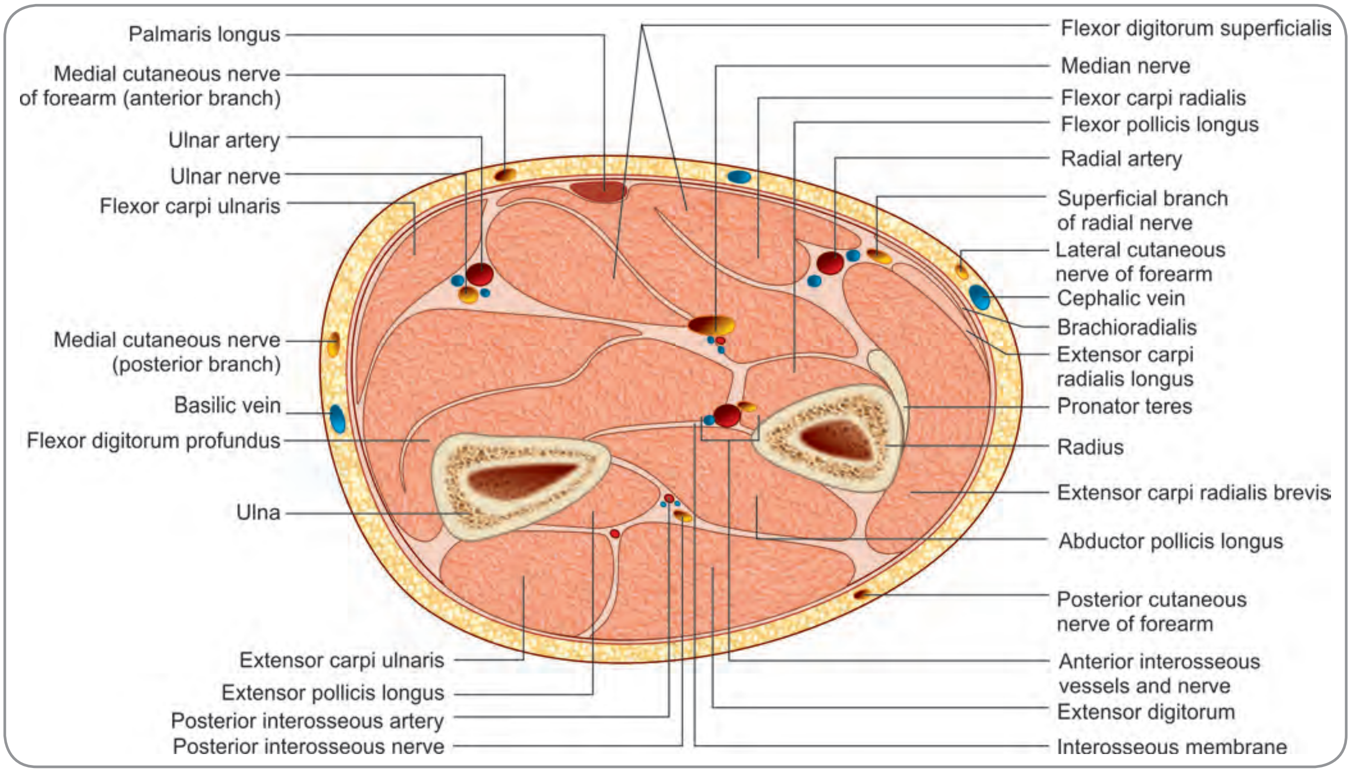


Fig. 20.5: Transverse section of the forearm at the middle of its length (mid forearm section)

between the two heads. The radial artery is also seen along the same imaginary line but a little more laterally. The ulnar nerve is located between the flexor carpi ulnaris and the flexor digitorum profundus

The extensor compartment of the forearm is clearly posterolateral. The supinator muscle is attached to the ulna and enwraps around the posterior and lateral aspects of radius. Lying superficial to the supinator, from the medial to lateral aspects are the anconeus, extensor carpi ulnaris, extensor digitorum, extensor carpi radialis brevis, extensor carpi radialis longus and brachioradialis. The superficial and deep (posterior interosseous) divisions of the radial nerve can be made out between the muscles.

Branches of the medial cutaneous nerve of forearm, lateral cutaneous nerve of forearm and posterior cutaneous nerve of forearm are seen in the superficial fascia on the respective aspects of the forearm.

- ***Transverse section of the forearm at the middle of its length (mid forearm section)*** (Fig. 20.5): This section shows the muscles of the flexor and extensor compartments of the forearm.

The two bones of the forearm are seen; they are connected by the interosseous membrane. The anterior aspect of the ulna and most of the interosseous membrane are clothed by the flexor digitorum profundus muscle. The anterior aspect of the radius is covered by the flexor pollicis longus muscle. The anterior interosseous nerve and vessels lie on the interosseous membrane between these two muscles. Anterior to the two muscles are (from medial to lateral) the flexor carpi ulnaris, the flexor digitorum superficialis and flexor carpi radialis. The tendon of pronator teres can be seen attaching to the radius on the lateral aspect and is overlapped by the fleshy fibres of extensor carpi radialis brevis and the tendons of extensor carpi radialis longus and brachioradialis. The median nerve is seen between the flexor digitorum superficialis and the flexor digitorum profundus. The ulnar nerve and the ulnar artery (along with the venae comitantes) can be seen lying on the flexor digitorum profundus deep to flexor carpi ulnaris. The radial artery (with its venae comitantes) and the superficial branch of radial nerve are located on the lateral aspect of the section, lying immediately beneath the deep fascia and overlapped by the anterior border of brachioradialis

The extensor muscles are seen posterior to the interosseous membrane. The extensor pollicis longus lies attached to the posterior aspect of ulna and the medial part of the posterior surface of the interosseous membrane. The abductor pollicis longus lies attached to the lateral part of the posterior surface of the interosseous membrane and the posterior aspect of radius. Superficial to these two muscles are the extensor carpi ulnaris (medially) and the extensor digitorum (laterally). The extensor carpi radialis brevis is seen curving around the lateral aspect of the radius and covering the tendon of pronator teres which had already sought attachment to the radius. Both the extensor radialis longus and the brachioradialis have moved

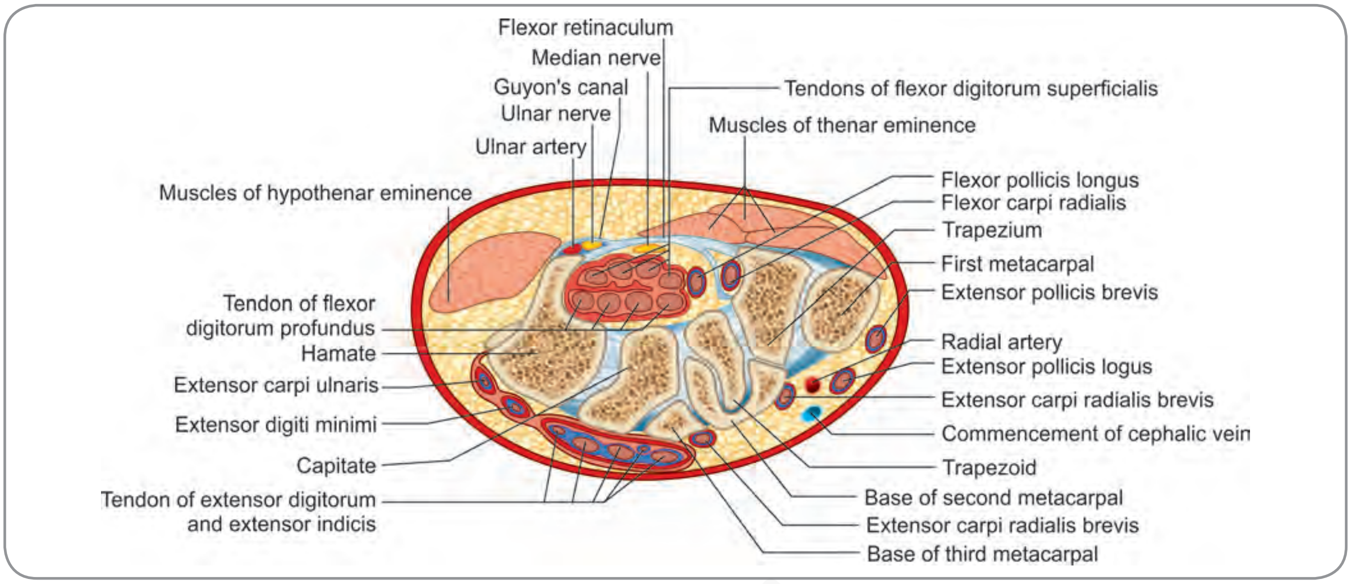


Fig. 20.6: Transverse section of the wrist

anteriorwards and their tendons are seen overlapping the extensor carpi radialis brevis. The posterior interosseous nerve and vessels can be seen between the superficial and deep muscles of the posterior compartment.

The basilic vein and the posterior branch of the medial cutaneous nerve of forearm are seen in the superficial plane on the medial aspect, the anterior branch of the medial cutaneous nerve of forearm in the superficial plane on the anterior aspect, the cephalic vein and the lateral cutaneous nerve of forearm in the superficial plane on the lateral aspect and the posterior cutaneous nerve of forearm in the superficial plane on the posterior aspect.

***Significance of the forearm sections*:** In all sections of the forearm, except if taken at the most distal part, the orientation of the flexor and the extensor compartments can well be made out. The flexor group muscles occupy the medial and anterior position; the extensor group occupies the lateral and posterior position. If a line has to bisect and separate the two compartments, the line necessarily would be oblique running from the posteromedial to the anterolateral aspect and not 'truly' transverse.

- ***Transverse section of the wrist*** (Fig. 20.6): This section is probably the most important of all the sections of the upper limb from a clinical perspective. It shows the disposition of the various tendons which cross the wrist to reach the hand.

The carpal bones are seen in section, they form an arch that is concave anteriorly. The section usually goes through the base of the first metacarpal and this bone can be made out lateral to the trapezium. The carpal arch is closed by the flexor retinaculum which stretches between the medial and lateral lips of the concavity. The carpal tunnel (seen as an enclosed space in this section) thus created is occupied by the various flexor tendons Eight tendons can be seen together in a single bunch in the medial portion of the tunnel. These are the tendons of flexor digitorum superficialis and flexor digitorum profundus; those of superficialis are superficial to those of profundus. The ulnar bursa can also be made out on keen observation. The tendon of flexor pollicis longus occupies the same tunnel, but the lateral portion and within its own tendon sheath The median nerve is seen as a prominent structure within the carpal tunnel superficial to all the tendons.

The tendon of flexor carpi radialis is located on the lateral aspect of the tunnel, not lying within the tunnel proper but occupying a separate compartment between the two divisions of the flexor retinaculum on the lateral aspect. This tendon also snugly fits into a groove on the medial aspect of trapezium. Superficial to the flexor retinaculum, on the medial side, are seen the ulnar nerve and the ulnar artery.

Still superficial on the anterior aspect can be seen the hypothenar muscles on the medial side and the thenar muscles on the lateral side.

The section also reveals the dorsum of hand. Extensor tendons can be made out on the dorsal aspect. A bunch of tendons can be made out almost at the middle portion. These are the tendons of extensor digitorum and that of extensor indicis. Medial to this bunch are the tendons of extensor digiti minimi and extensor carpi ulnaris. Immediately lateral to the bunch of tendons is the tendon of extensor carpi radialis brevis A little more lateral are the tendons of extensor carpi radialis brevis, extensor pollicis longus and extensor pollicis brevis (in that order from medial to lateral). The tendon of abductor pollicis longus is not seen because it would have already reached its insertion. The cephalic vein can be seen in the superficial fascia of the dorsum.

Significance of this level: The carpal tunnel is an important anatomical entity. Its true significance is appreciated only when it is realised that the median nerve traverses through a tight compartment and is likely to be compressed even in cases of mild alterations of dimensions. The placement of the nerve can well be seen in this section.

RADIOLOGICAL ANATOMY OF UPPER LIMB

Since the bones are radio-opaque, disorders and problems involving the bones, joints and related structures are well analysed with the help of radiographs or X-rays.

As a radiographic picture is taken up of study, the following familiar steps should be gone through. The steps are:

- Identification of the area of the radiograph preferably with the concerned view (e.g. PA view, oblique view, etc.);
- Identification of all the visible bony landmarks by name
- Checking on the relations of the various bones and joints seen;
- Identification of the normal joint space;
- Identification of epiphysis if any.

It is therefore imperative to notice and record any abnormality seen with regard to the aforementioned features.

Special and exclusive features of the concerned area should also be studied.

Shoulder Region (Fig. 20.7)

A radiograph of the shoulder region usually shows the shoulder and a small portion of the thorax.

Bones and Bony Landmarks

- In anteroposterior view, the scapula, coracoid and glenoid are clearly visible; the acromion and the acromioclavicular joint are also made out (all of the concerned side);
- Clavicle, especially its lateral portion and lateral end;
- Humerus (of the concerned side), its tubercles, anatomical and surgical necks;
- Ribs.

Joints

Shoulder joint and acromioclavicular joint; joint spaces and widening of spaces if any should be noted and recorded.

Specific Features

- Greater tuberosity is seen as the most lateral bony point.
- Anatomical neck of humerus will be seen as an angular notch; its medial part will be on level with the junction of the middle and lower thirds of glenoid.

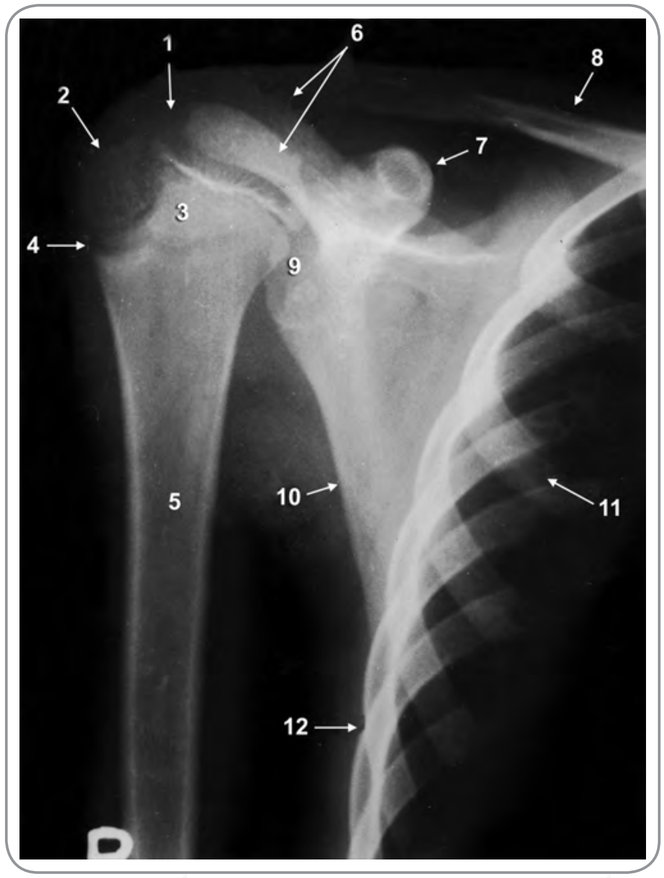


Fig. 20.7: 1. Head of humerus. 2. Greater tubercle. 3. Lesser tubercle. 4. Epiphyseal plate of upper end of humerus. 5. Shaft of humerus. 6. Outline of acromion process (partially overlapping the head of humerus). 7 Coracoid process. 8. Clavicle. 9. Glenoid cavity. 10. Lateral border of body of scapula. 11. Medial border of body of scapula. 12. Ribs forming wall of thorax. Radiograph of the region of the shoulder in a child about 10 years old. Ossificaiton of the upper end of the humerus is not complete. The centes for the head, the greater tubercle and the lesser tubercle are seen separately. The epiphyseal plate separating the upper end from the diaphysis is clearly seen. The shadow of the scapula is overlapped (in its medial part) by the thoracic cage (made up of r bs). The med al margin of the scapula can be made out (as the ribs appear lighter where they overlap the scapula). The acromion, the coracoid process and the clavicle can be distinguished. The tip of the coracoid process is seen as a circular area as it is viewed head on

Humerus Bone

The upper and lower ends of the bone articulate with other bones to form the shoulder and the elbow joints respectively. The respective joint spaces are seen. Any widening should be noted and recorded.

Secondary centres of ossification and non-fusion of epiphyses may be seen depending upon the age of the individual. As a corollary, age of the individual can be estimated with the help of the radiograph. This factor is of medicolegal importance.

Elbow Region (Fig. 20.8)

Bones and Bony Landmarks

Lower end of humerus with its epicondyles, capitulum and trochlea of humerus, head and tuberosity of radius, olecranon of ulna.

Joints

Elbow with its joint space—the joint space is seen as a broadline across the ulna between the trochlea and coronoid process; it extends laterally between the capitulum and the radial head. In a lateral view, the capitulum can be seen projecting anterior to the line of shaft of humerus. Supracondylar ridges may also be visible as white oblique lines passing above from the epicondylar shadows.

Fig. 20.8: 1. Shaft of humerus. 2. Olecranon fossa. 3. Epiphyseall plate of lower end of humerus. 4. Conjoint epiphysis for capitulum and lateral epicondyle of humerus. 5. Upper epiphysis of radius 6. Epiphysis for medial epicondyle 7 Olecranon, medial margin. 8. Coronoid process. 9. Radial tuberosity. 10. Shaft of radius. 11. Shaft of ulna. Radiograph of the region of the elbow in a child about ten years old. At the lower end of the humerus the conjoined epiphysis for the capitulum and lateral epicondyle can be seen separated from the diaphysis by an epiphyseal plate. The medial epicondylar epiphysis is also separate from the shaft. The upper epiphysis of the radius (unfused with the shaft) is clearly seen

Bones of Forearm

A radiograph showing the bones of the forearm will show the elbow joint, the radioulnar joints and the wrist joint. The joint spaces should be observed and studied. Presence of epiphyses and bony markings should be noted apart from searching for abnormalities like fractures.

Wrist Region and Hand (Fig. 20 9)

Lower ends of radius and ulna, carpal bones, metacarpal bones and phalanges with the intervening joints will be seen. Radioulnar, radiocarpal, midcarpal, intercarpal and interphalangeal joint spaces will also be seen. A posteroanterior view shows the two rows of carpal bones

Fig. 20.9: 1. Distal phalanx. 2. Epiphysis of distal phalanx. 3. Middle phalanx. 4. Epiphysis of middle phalanx. 5. Proximal phalanx. 6. Epiphysis of proximal phalanx. 7. Epiphysis at distal end of second metacarpal bone. 8. Second metacarpal. 9. Fi st metacarpal. 10. Epiphysis at proximal end of first metacarpal bone. 11. Trapezium. 12. Scaphoid. 13. Distal epiphysis of radius. 14. Shaft of radius. 15. Trapezoid. 16. Capitate. 17. Hamate. 18. Triquetral bone. 19. Lunate. 20. Distal epiphysis of ulna. 21. Shaft of ulna. Radiograph of the hand and wrist in a child about ten years old. Note that each phalanx (distal, middle and proximal in each digit other than the thumb; and only proximal and distal in the thumb) has an epiphysis at its proximal end. The second, third, fourth and fifth metacarpal bones have an epiphysis each at their distal ends. The first metacarpal bone is different in that its epiphysis is at the proximal end (l ke a phalanx). Idendify the various carpal bones. (The pisiform bone cannot be made out in this radiograph). Finally note the unfused epiphyses at the lower ends of the radius and ulna

clearly. Bases of the metacarpals are not very clear and tend to overlap.

Specific Features

Presence of sesamoids—most of the sesamoids of the hand are constant; two sesamoids opposite the head of the first metacarpal, one opposite the head of the fifth metacarpal and one opposite the interphalangeal joint of thumb are usually seen. The last may be infrequent.

IMPORTANT LINES AND AREAS

Some areas and regions are marked by some landmarks or by imaginary lines connecting certain landmark points. These areas and regions are important in that they form a guide to internal structures.

- ***Clavicle as the 'divide':*** It is the divide between the neck and the thorax. It is also the 'divide' between the deep cervical and axillary lymph sheds. Above the clavicle is the area of deep cervical lymph drainage; below is the area of axillary lymph drainage.
- ***Deltopectoral triangle:*** This is a small triangular depression (also called the infraclavicular fossa) marked on the anterior chest wall immediately inferior to the clavicle. The triangle has an inferiorly placed apex and a superiorly placed base. The side lines of the triangle are the superolateral border of pectoralis major and the anterior border of deltoid. The apex is where the two lines meet. The base is formed by the lateral third of the clavicle.
- ***Anterior axillary fold:*** This is the anterior boundary of axilla and can be held between the thumb and forefinger of the palpating hand. It is formed by the lower border of the pectoralis major muscle and is made prominent by making the individual press upon his/her hip on the same side with the hand. The fold is also made prominent if the abducted arm is adducted against resistance.
- ***Posterior axillary fold:*** This is the posterior boundary of axilla and can be held between the thumb and the forefinger of the palpating hand It is formed by the tendon of latissimus dorsi muscle
- ***Cubital fossa:*** This is a depression in the front of the elbow. The depression can be well felt between the medial prominence formed by the pronator teres muscle and the lateral prominence by the brachioradialis muscle.
- ***Transverse creases of the wrist:*** Two prominent creases are seen on the front of the wrist. The proximal crease marks the level of the wrist joint. The distal crease marks the proximal border of flexor retinaculum
- ***Anatomical snuff box:*** It is a small depression on the posterolateral aspect of the wrist, immediately distal to the radial styloid. Its medial boundary is the tendon of extensor pollicis longus; lateral boundary is formed by tendons of abductor pollicis longus and extensor pollicis brevis. The base of the space is formed by radial styloid (proximally) and the base of the first metacarpal (distally). The radial artery can be palpated in the space as the artery winds around the lateral border of the wrist to reach the dorsum of hand. Cephalic vein may sometimes be crossing the space.
- ***Flexion creases of wrist and hand:*** Several such creases are found, some are constant, some are variable. These are places where the skin and the deep fascia are firmly bound to each other
  - ***Wrist creases:*** There are usually two; (1) the proximal and (2) the distal. The distal crease is more prominent and is seen as a kind of a dividing line between the front of forearm and the palm. This is the level at which the palm appears to widen from the borders of the forearm. The proximal crease is fainter and is 2 cm proximal to the distal crease and so appears to be on the front of forearm. The distal crease marks the proximal border of the flexor retinaculum. The proximal crease marks the wrist joint. There may be an additional middle crease.
  - ***Palmar creases:*** There are many of them. They may be classified as longitudinal and transverse. The radial longitudinal crease starts in the middle of the root of thumb and encircles the thenar eminence. Though considered important, it is a comparatively faint crease. The thenar longitudinal crease is more prominent. It starts close to or in union with the proximal transverse crease on the radial border of hand. It continues towards the wrist forming a medial convexity to the radial longitudinal crease. The proximal transverse crease starts on the radial border of palm at the level of the head of the second metacarpal bone. It runs medially and a little upwards to the medial border. The distal transverse crease starts at or near the cleft between the index and middle fingers and then proceeds to the medial border with a convexity on the proximal radial aspect.
  - ***Digital creases:*** There are three digital creases ((1) proximal, (2) middle and (3) distal) in each of the medial fingers; the proximal is about 2 cm distal to the metacarpophalangeal joint; the middle is over the proximal interphalangeal joint; the distal crease is immediately proximal to the distal interphalangeal joint. The thumb has only two creases.

SUPERNUMERARY BONES

Some additional bones may be found in the upper limb. These are usually small in size and do not produce symptoms. Due to their small sizes, they are often called

the supernumerary ossicles. The most common of such ossicles are:

- ***Ossiculum infrascapulare:*** A small bone near the inferior angle of scapula due to failure of fusion;
- ***Ossiculum acromiale:*** Separate part of the acromion of the scapula;
- ***Bifurcate clavicle:*** Medial end of clavicle is split into two resembling the shape of a catapult that is placed horizontal; sometimes called the 'catapult clavicle';
- ***Sesamoid bone*** in the bicipital tendon near the radial tuberosity;
- ***Sesamoid bone*** in the triceps tendon; considered to be a true sesamoid bone, it is usually referred to as the 'ossiculum, patella cubiti';
- ***Ossiculum Supretrochleare dorsale:*** A separate ossicle in the olecranon fossa of humerus; may interfere with movements of elbow, especially extension;
- *Almost regular* ***sesamoid bones:*** Two at the metacarpophalangeal joint of thumb, one at the interphalangeal joint of index finger and one each at the metacarpophalangeal joint of index finger and that of the little finger;
- ***Ossiculum radiostyloideum:*** Separate styloid process of radius;
- ***Ossiculum gruberi:*** Separate ossicle between the hamate and the related metacarpal bones.

Apart from the above mentioned supernumerary ossicles, as many as 24 supernumerary ossicles have been described in relation to the various carpal bones.

SURFACE MARKING OF IMPORTANT BONY POINTS AND STRUCTURES OF UPPER LIMB

Bony Points and Planes

- ***Suprasternal notch:*** Though it is on the anterior wall of the chest, it is an important landmark in studying the structures of the upper limb. It is formed by the superior margin of manubrium sterni and is palpated as a depression in the midline, between the medial ends of the two clavicles.
- ***Sternal angle:*** It is the angle between the manubrium and the body of sternum. It is felt as an elevation when the palpating finger is run down from the manubrium on the midline itself. The sternal angle, otherwise called the angle of Louis, indicates the level at which the second costal cartilages join the sternum. After palpating the angle, if the palpating finger is run laterally, the second costal cartilage can be felt. Locating the second costal cartilage will help in the counting of ribs.
- ***Medial end of clavicle:*** It is the prominence that can be felt above the margins of manubrium sterni.
- ***Coracoid process of scapula:*** It is felt about 2.5 cm vertically below the junction of the lateral one fourth of the clavicle with the medial three-fourths.
- ***Tip of acromion:*** It is felt lateral to the acromioclavicular joint.
- ***Crest of scapular spine:*** It is felt clearly throughout its length; its medial end is opposite the third thoracic spine
- ***Acromial angle:*** It is felt at the point where the crest of spine turns to become the lateral border of the acromion.
- ***Inferior angle of scapula:*** It is felt clearly as the medial border of the bone is traced down; the angle is at the level of the T7 spine.
- ***Greater tuberosity of humerus:*** It is the most lateral bony point in the shoulder region.
- ***Lesser tuberosity of humerus:*** It can be marked and felt about 3 cm below the acromial tip on the anterior aspect of the shoulder.
- ***Medial epicondyle of humerus:*** It is seen and felt as a prominence on the medial aspect of the elbow. It is easily felt if the elbow is flexed.
- ***Lateral epicondyle of humerus:*** It is felt in the depth of a depression present on the posterior aspect of the elbow.
- ***Olecranon and its prominence:*** It is felt immediately medial to the midpoint of the inter epicondylar line on the posterior aspect of the extended elbow. In a flexed elbow, the epicondyles and the olecranon make a clear isosceles triangle
- ***Posterior border of ulna:*** It can be felt as a continuous subcutaneous surface from the olecranon to the ulnar styloid.
- ***Head of radius:*** It is felt below the lateral epicondyle in the same depression wherein the epicondyle is felt. It can be felt easily, if the forearm is alternately supinated and pronated.

  Feeling for the head and neck of radius: Flex the elbow (of the person whom you are examining)slightly. Place your hand over the elbow so that the thumb is in front and the fingers behind With the index finger locate the line of the elbow joint, near its lateral part and slip the finger slightly below this level. Now alternately supinate and pronate the forearm. By moving your finger you will be able to feel the head of the radius as it rotates. The neck of the radius lies just below the head.
- ***Lower end of radius:*** It is seen as a small lateral prominence at the level of the wrist.
- ***Dorsal tubercle of radius:*** It is seen and felt on the posterior aspect of the lower end of radius in line with the space between the index and middle fingers.
- ***Styloid of radius:*** It can be felt easily on the lateral aspect of the lower end of radius. It is about 1.75 cm below and slightly anterior to the ulnar styloid.
- ***Head of ulna:*** It is seen and felt as a rounded prominence on the medial side of the posterior aspect of the wrist (especially prominent in pronation).

- ***Styloid process of ulna:*** It is felt projecting downwards from the ulnar head. Follow the posterior border of ulna downwards and determine the ulnar head.
- ***Pisiform bone:*** It is felt as a rounded prominence on the hypothenar eminence.
- ***Hook of hamate:*** It is distal to pisiform and on a deeper plane. It is marked about 2.5 cm below and lateral to pisiform in line with the medial border of the ring finger.
- ***Tubercle of scaphoid:*** It is present on the base of the thenar eminence. Feel for the tendon of flexor carpi radialis in this area. Immediately lateral to the tendon, a small depression can be felt. The tubercle of scaphoid can be felt in this depression.

Vessels

- ***Axillary artery:*** The arm is abducted to the level of the shoulder (that is to a right angle). Point A is marked on the middle of clavicle. Point B is marked on the medial border of the prominence of coracobrachialis. These two points are joined by a broadline that marks the axilllary artery. In the abducted position, the artery is straight. If the arm is hanging by the side of trunk, the artery will have a curved course with the concavity directed downwards and medially.
- ***Brachial artery:*** It is preferable to mark the brachial artery with the arm abducted to the level of the shoulder. Point A is marked on feeling the pulsation of the axillary artery immediately anterior to the posterior axillary fold. Alternately, point A can be marked on the medial border of the prominence of coracobrachialis in an abducted arm. Point B is marked at the level of the neck of radius in the midline of the limb (grossly, about 1 cm beyond the bend of elbow on the midline). A broadline connecting these two points marks the brachial artery.
- ***Radial artery:*** Point A is marked opposite the neck of radius immediately medial to the tendon of biceps. Point B is marked exactly on the pulsation of the artery as it is usually palpated on the anterior surface of lower part of radius. Point C is marked on the pulsation of the artery in the anatomical snuff box. Points A and B are joined by a line that runs downwards and slightly curved to the lateral side. Points B and C are joined by a line passing downwards and backwards across the tendons forming the anterior boundary of the anatomical snuff box. The complete stretch of line indicates the radial artery. The curved connecting points A and B marks the artery in the forearm. The line between points B and C marks the artery as it runs into the hand. One more point D can be marked at the proximal end of the first intermetacarpal space on the dorsal aspect. A line joining points C and D will indicate the artery in the hand.
- ***Ulnar artery:*** Point A is marked opposite the neck of radius immediately medial to the tendon of biceps. Point B is marked on the medial aspect of the anterior surface of the forearm (close to the medial border) at the level of the junction of the upper third with the lower two-thirds. Point C is marked immediately lateral to pisiform bone. The first two points are connected by a broadline which is slightly convex to the medial aspect. Then it is extended to the third point by a straight line. The complete stretch of line marks the ulnar artery.
- ***Lower part of ulnar artery:*** Point A is marked on the front of medial epicondyle. Point B is marked immediately lateral to pisiform. The lower two-thirds of the line connecting these two points corresponds to the lower two-thirds of the ulnar artery.
- ***Superficial palmar arch:*** Point A is marked immediately lateral to pisiform bone. Point B is marked on the hook of hamate which is distal to pisiform at a deeper level. Point C is marked on the middle of the palm in line with the distal border of an extended thumb. Point A and B are connected by a broadline that is slightly curved and runs to the medial side of point B. From point B, the line is continued to point C as a curve with its convexity outwards. The line is further continued in the same arc of circle to reach the middle of the thenar eminence. The point on the thenar eminence (point D) can be checked to be midway between the root of middle finger and the most distal of the skin creases of the wrist. The curved line indicates the superficial palmar arch.
- ***Deep palmar arch:*** This is marked by a transverse line (with a slight curve distally) about 1–2 cm proximal to the superficial arch. On the medial aspect, a curved line can be drawn from the medial end of the transverse line to the hook of hamate.
- ***Axillary vein:*** The points to be marked are as same as those for marking the axillary artery. However, the line indicating the axillary vein should be drawn a little medial to that would be drawn for the artery.

Nerves

- ***Axillary nerve:*** Only part of the course of the nerve can be marked on the surface. The arm is abducted to the level of the shoulder. The marking is done on the posterior aspect. The insertion of deltoid is felt for and marked. The tip of acromion is also marked. The tip of acromion and the deltoid insertion (approximately indicating the deltoid tuberosity) are connected by a line. Point A (for axillary nerve) is marked 2 cm lateral to the midpoint (above in the abducted position of the arm) of the above described line. A transverse line drawn across the deltoid muscle from point A indicates the axillary nerve.
- ***Median nerve:*** It is easy to mark the median nerve in two parts: (1) the part in the arm and (2) the part in the forearm.

1. ***Part in the arm:*** The brachial artery is first marked. A line drawn on the lateral aspect of the marked artery in the proximal half and on the medial aspect in the distal half with a crossing over the artery in the middle indicates the median nerve on the surface.
2. ***Part in the forearm:*** Point A is marked at the level of the neck of radius in the midline of the limb (grossly, about 1 cm beyond the bend of elbow on the midline). Point B is marked at the wrist about 1 cm medial to the tendon of flexor carpi radialis. A line joining the two points indicates the median nerve in the forearm.

- ***Musculocutaneous nerve:*** The arm is abducted to the level of the shoulder. The coracoid process is felt for point A is marked about 3 cm below the coracoid process. The elevation caused by the biceps muscle is felt for and point B is marked in the middle of the elevation. Point C is marked immediately lateral to the bicipital tendon. A line joining all the three points indicates the musculocutaneous nerve on the surface. Point C also indicates the point where the musculocutaneous nerve continues as the lateral cutaneous nerve of the forearm
- ***Radial nerve:*** The radial nerve is marked in two parts: (1) the part in the arm and (2) the part in the forearm.
  1. ***Part in the arm:*** The arm is abducted to the level of the shoulder. The commencement point of the brachial artery is first marked. A point at the same level is marked on the posterior aspect also (this marking will be on the posterior aspect of the posterior axillary fold). It will be point A for radial nerve. The insertion of deltoid is then joined by a line to the posterior aspect of the lateral epicondyle. Mark a point at the junction of the upper and middle thirds of this line. This will be point B. Point C is marked on the anterior aspect at the level of the lateral epicondyle about 1.5 cm lateral to the bicipital tendon. All the three points are joined by a line which will be oblique and cross the elevation produced by the triceps muscle. This oblique line marks the radial nerve in the arm.
  2. ***Part in the forearm:*** Point A is marked on the anterior aspect of the forearm at the level of the lateral epicondyle about 1 5 cm lateral to the bicipital tendon. Point B is marked at the junction of the middle and the lower thirds of the lateral border of the forearm. Point C is marked in the anatomical snuff box immediately lateral to the radial artery. Point A and B are joined by a line that is curved towards the lateral aspect. Point B and Point C are joined by a line that runs inferiorly. The whole stretch indicates the radial nerve in the forearm
- ***Ulnar Nerve:*** The ulnar nerve is marked in two parts: (1) the part in the arm and (2) the part in the forearm.
  1. ***Part in the arm:*** The arm is abducted to the level of the shoulder. The brachial artery is first marked. Also mark the midpoint of the brachial artery. Point A for ulnar nerve is the commencement of brachial artery. Point B is midpoint of brachial artery. Point C is marked on the posterior aspect of the medial epicondyle by rolling the ulnar nerve there. Join points A and B by a line that is about 1 cm medial to the brachial artery. Join points B and C by a line that winds around the medial border of the arm and reaches the posterior aspect. The whole stretch from point A to point C indicates the ulnar nerve in the arm.
  2. ***Part in the forearm***: Point A is marked on the lower aspect of the medial epicondyle of humerus. Point B is marked immediately lateral to the pisiform bone. The two points are joined by a line that follows the tendon of flexor carpi ulnaris in its lower half. This line indicates the ulnar nerve in the forearm.
- ***Posterior interosseous nerve:*** The posterior interosseous nerve can be marked on the posterior aspect of the forearm. Point A is marked on the anterior aspect of the forearm at the level of the lateral epicondyle about 1.5 cm lateral to the bicipital tendon. Join the posterior aspect of radius to the dorsal tubercle of radius. Point B is marked at the junction of the upper third of this line to its middle third. Point C is marked on the dorsal tubercle of radius. All the three points are joined by a line that is curved in the upper part

Others

- ***Shoulder joint:***
  1. Joint line in front – Point A is marked on the coracoids process. Drop a vertical line for about 7 cm from this point. This line indicates the shoulder joint line.
  2. Joint line at the back – Point A is marked on the acromial angle. Drop a vertical line for about 8 cm from this point This line indicates the shoulder joint
- ***Elbow joint:*** Since the elbow joint cavity is irregular in shape, both the proximal and distal limits of the joint cavity can be marked separately.

  Distal line on the anterior aspect: Point A is marked 2 cm below the medial epicondyle. Point B is marked 2 cm below the lateral epicondyle. The two points are joined by a line which is directed inferomedially.

  Distal line on the posterior aspect: Point A is marked on the medial border of the coronoid process of ulna at the level of its tubercle. Point B is marked in the depression between the lateral epicondyle and head of radius. The two points are joined by a transverse line.

  Proximal line on the anterior aspect: Point A is marked just above the tubercle on the coronoid process Point B is marked on the medial epicondyle at its most

lateral point. Point C is marked on the front of the lateral epicondyle. Point D is marked on the head of radius. All the four points are joined by a line that has an inverted 'U' shape. This line indicates the proximal line of the joint cavity.

Proximal line on the posterior aspect: Point A is marked on the medial border of the coronoid process of ulna at the level of its tubercle. Point B is marked in the depression between the lateral epicondyle and head of radius. The two points are joined by an arched line that is parallel but 1 cm wider to the curve of the olecranon. This line indicates the proximal line of the joint cavity.

- ***Wrist joint:*** A transverse line across the front of the wrist is drawn about 2.5 cm proximal to the ball of the thumb. This marks the joint plane of the wrist. To mark the joint plane on the posterior aspect, a transverse line is drawn across the wrist immediately distal to the head of ulna. The joint cavity can be indicated by a curved line a little higher than the lines of joint plane.
- ***Metacarpophalangeal joints:*** These are marked about 2 cm proximal to the junction lines of the digits to the palm.
- ***Extensor retinaculum:*** The upper and the lower borders of the retinaculum can be marked Point A is marked on the anterior border of the radius 2 cm above its lower end. Point B is marked on the styloid process of the ulna. Both these points are joined by a line that passes around the lateral side and back of the wrist. This is the upper border of the extensor retinaculum. Point C is marked on the lower end of the anterior border of the radius. Point D is marked on the triquetral bone. Points C and D are joined by a line that is parallel to the upper border. This line marks the lower border of the extensor retinaculum.
- ***Flexor retinaculum:*** The upper border of the flexor retinaculum corresponds to a line joining the pisiform bone to the tubercle of the scaphoid bone. The upper border should be drawn with a slight concavity upwards. The lower border corresponds to a line joining the hook of the hamate to the tubercle of the trapezium. The lower border should be drawn with a slight concavity downwards. The medial and lateral margins are drawn by connecting the corresponding ends of the upper and lower borders to one another.

PLACES WHERE PULSATIONS CAN BE FELT

- ***Axillary artery:*** Palpated behind the anterior wall and against the lateral wall of axilla by pressing the examining fingers gently upwards and laterally.
- ***Brachial artery:*** Palpated on the anteromedial aspect of the arm in a furrow that is anterior to coracobrachialis in its upper part and medial to biceps in its lower part.
- ***Radial artery***: Palpated at the wrist over the radius, proximal to the base of the thumb.
- ***Ulnar artery:*** Palpated lateral to the pisiform bone.
- ***Princeps pollicis artery:*** Palpated in the cleft between the thumb and the index finger.
- ***Radialis indicis artery:*** Palpated on the lateral aspect of the metacarpal of the index finger.

MAKING TENDONS OF MUSCLES PALPABLE

During the course of examination of a patient, it may be necessary to make certain tendons prominent, so as to palpate them and the related areas.

- ***Pectoralis major:*** The clavicular head of this muscle can be made palpable when the arm is flexed to a right angle.
- ***Deltoid:*** The insertion of this muscle is identified if the arm is kept abducted. The entire muscle is prominent and tightened in this position.
- ***Biceps:*** Both the muscle and its tendon are made prominent when the elbow is flexed. The tendon can be felt and sometimes seen in the cubital fossa in this position.
- ***Flexor carpi radialis:*** The tendon of this muscle can be felt on the lateral aspect of the lower anterior forearm if the wrist is flexed against resistance.
- ***Flexor carpi ulnaris:*** The tendon of this muscle can be felt on the medial aspect of the lower anterior forearm if the wrist is flexed against resistance.

Multiple Choice Questions

1. The most lateral bony point in X ray shoulder is
   a. Acromion
   b. Greater tuberosity of humerus
   c. Lateral end of clavicle
   d. Anatomical neck

2. The structure that serves as a divide between deep cervical and axillary lymph sheds is
   a. Clavicle
   b. Mammary gland
   c. Deltopectoral groove
   d. Basilic vein

3. A catapult bone is
   a Bifurcate clavicle
   b. Split scapula
   c. Normal radius
   d. Bent humerus

4. A transverse line drawn about 1.5 cm proximal to the superficial palmar arch indicates the
   a. Deep palmar arch
   b. Flexor retinaculum
   c. Middle palmar crease
   d. Proximal border of adductor pollicis

5. Inferior angle of scapula corresponds to
   a. T7 spine
   b. T8 spine
   c. T9 spine
   d. T6 spine

ANSWERS

1. b **2.** a **3.** a **4.** a **5.** a

Clinical Problem-solving

Case Study 1: You are given the X ray picture of the left shoulder of a 12 year old boy. At the upper end of the humerus, you find separate opaque areas. The bony contour remains intact but the bone seems to be in pieces.

- What is abnormal about this X ray?
- What causes the appearance of the separate parts?
- In what way can this X ray be used for evaluating the patient?

Case Study 2: Your medical colleague is about give an intramuscular injection to a patient in the upper arm area. The patient holds the arm in abduction and your colleague insists that he should not do so.

- Do you think your colleague is correct in asking the patient not to keep the arm abducted?
- What happens in abduction of arm?
- In what way is the position of abduction advantageous / disadvantageous?

(For solutions see Appendix).

Section 3

Lower Limb

Chapter 21

Overview of Lower Limb

Frequently Asked Questions

- List out the cutaneous innervation of gluteal region.
- Describe the cutaneous innervation of dorsal aspect of toes.
- Discuss the great saphenous vein.
- Write in detail about the superficial veins of lower limb
- Write notes on perforating veins.
- Write notes on inguinal lymph nodes.

REGIONS OF LOWER LIMB (FIG. 21.1)

The lower limb is an extension from the lower part of the trunk and is specialised to bear the weight of the body, help the individual move from place to place and maintain balance both while stationary and moving. The bones of the lower limb are attached to the axial skeleton by the pelvic girdle.

For the sake of convenience and easy description, the lower limb can be subdivided into various regions. These regions are:

- ***Thigh (regio femorae):*** It is the part of the limb between the hip and the knee; since femur is the bone of the thigh, the front of thigh is frequently called the femoral region. That part of front of thigh immediately inferior to the inguinal ligament is called the subinguinal region.
- ***Gluteal region (regio gluotos):*** It is the region on the posterior aspect and is seen as the prominently rounded buttocks; it is also called the natal area or the cluneal region.
- ***Hip region (regio coxae):*** It is the area of the hip joint and is concealed under the more prominent gluteal region, of which technically it is a part.
- ***Knee region (regio genus):*** It is area of the knee joint and is one of the prominently visible parts of the lower limb.

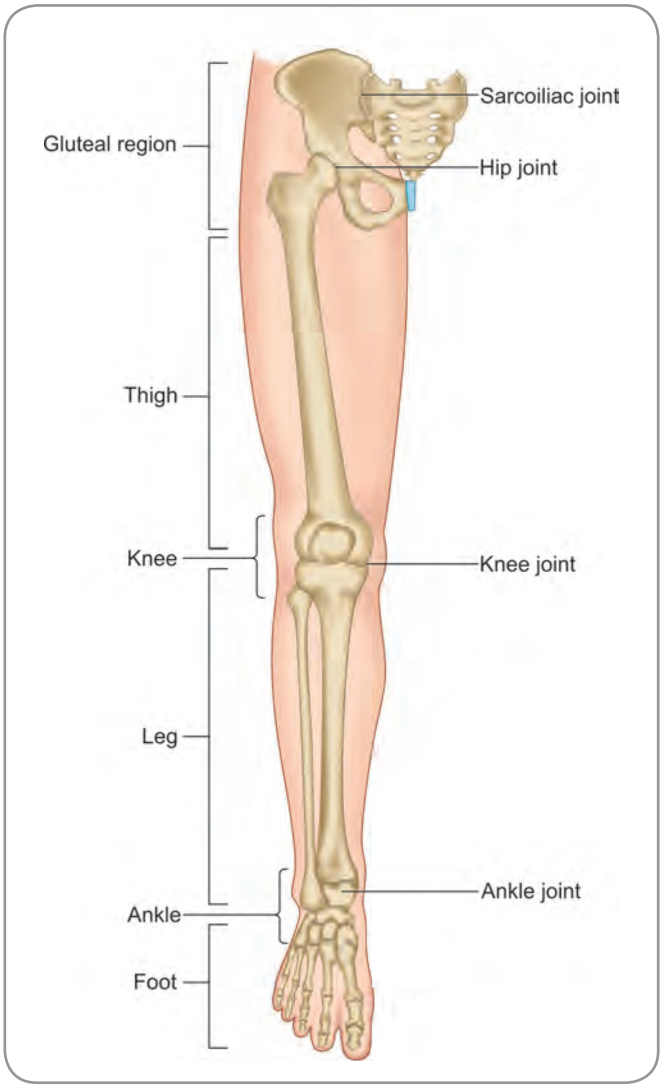


Fig. 21.1: Regions of the lower limb

Table 21.1: Major parts of lower limb, their extent and features

Part	Entent	Bones	Joints
Gluteal region	On the side and back of pelvis	Hip bone (pelvis)	Hip joint
Thigh	From hip to knee	• Femur • Patella	Knee joint
Leg	From knee to ankle	• Tibia • Fibula	• Tibiofibular joint • Ankle joint
Foot	From heel to toe	• Tarsals (7) • Metatarsals (5) • Phalanges (14)	• Intertarsal joints (e.g. subtalar transverse talar etc) • Intermetatarsal joints • Metatarsopharyngeal joint • Interphalangeal joint

- ***Leg (regio cruris):*** It is part of the limb between the knee and the ankle; the upper part of its posterior aspect is often referred to as the 'calf'.
- ***Popliteal region (regio poples):*** It is the posterior aspect of the knee.
- ***Ankle region (regio talocruralis):*** It is the region of the ankle joint and is the area where the vertical disposition of the limb changes to a horizontal disposition.
- ***Foot (regio pedis)*** It is the most distal part of the limb which in humans is laced horizontally

A brief summary of the four major parts of the lower limb is given in Table 21.1.

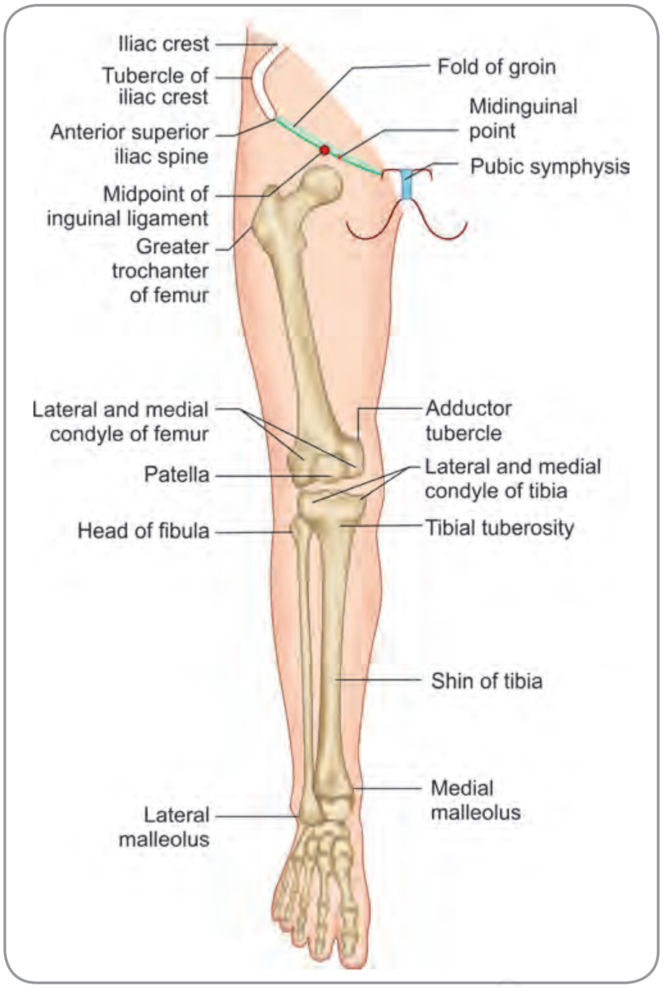


Fig. 21.2: Bony landmarks of the lower limb

Surface Landmarks (Fig. 21.2)

As the study of the lower limb is commenced, it is essential to know some of the important landmarks of the limb which are frequently referred to.

- ***Anterior superior iliac spine (ASIS):*** It is an easily palpable bony point at the lateral end of the junctional crease between the anterior abdominal wall and the thigh.
- ***Iliac crest:*** Running posteriorly, with a superior convexity from the ASIS is the iliac crest.
- ***Tubercle of the iliac crest:*** It can be palpated about 5 cm behind the ASIS on the iliac crest.
- ***Pubic symphysis:*** It is felt in the midline at the lower limit of the anterior abdominal wall. The upper edge of bone that can be palpated lateralwards from the pubic symphysis is called the pubic crest and the lateral end of the pubic crest is the pubic tubercle.
- ***Greater trochanter of femur:*** It can be felt about a hand's breadth below the iliac crest on the lateral aspect.
- ***Patella:*** Commonly called the knee cap, this bony prominence is well seen and felt in the anterior aspect of the knee.
- ***Tibial tuberosity:*** It is a bony prominence felt about 4–5 cm below the patella on the anterior aspect of the leg.
- ***Condyles of femur and tibia:*** These prominences can be palpated in the knee region.
- ***Shin of tibia:*** It is the thin and sharp anterior border of tibia, palpable almost throughout its extent.
- ***Head of fibula:*** It is a prominence felt on the posterolateral aspect of the knee and is in line with the upper edge of tibial tuberosity. Below the head, the neck of fibula is also palpable.
- ***Medial and lateral malleoli:*** These are two prominences felt on the medial and lateral aspects of the ankle region.
- Several bony prominences can be made out in the foot region. ***Calcaneus*** is palpable on its posterior, medial and lateral aspects. ***Sustentaculum*** tali is a small prominence about a finger breadth below the tip of medial malleolus. ***Peroneal trochlea*** is a small prominence on the lateral aspect, about 2 cm below the tip of lateral malleolus. Head of the first metatarsal bone is a prominent landmark on the medial aspect of the distal foot Tuberosity of the fifth metatarsal bone is felt at the midpoint of the lateral margin of the foot.

Development

Synopsis of lower limb development

The lower limb bud can be seen as a small outpouch from the ventrolateral body wall, caudal to the gut diverticulum, by about the end of fourth week or early fifth week of intrauterine life. The bud, as in the case of the upper limb bud, has a central core of mesenchyme covered by cuboidal ectoderm. Ectoderm at the distal border thickens to form the apical ectodermal ridge. The mesenchyme proliferates rapidly; the bud lengthens; the proximal mesenchyme starts differentiating into cartilage and muscles; and thus the forerunner of the adult limb is established.

By the sixth week, the distal most portion flattens to form the foot plate; it is separated from the rest of the limb bud by a circular constriction. Within the next few days, another constriction appears in the proximal portion, approximately dividing it into two equal halves. Thus, by the eighth week, rudiments of thigh, leg and foot are seen. Cell death occurs in the apical ectodermal ridge n such a way that five toes are culled out; the toes grow further to lengthen; internal differentiation causes cartilaginous phalanges, rudimentary tendons and fore runners of blood vessels to form; further cell death proceeds to establish inter digital space and separation. In the thigh and leg segments, extensor muscles develop on the dorsal aspect and the flexors on the ventral aspect of the cartilaginous rods which will subsequently become the bones of thigh and leg.

As the above changes are happening, rotation of the bud takes place in the seventh week. The time the limb bud started out pocketing, it comes to have a central axis; all development occurs symmetrically around the axis. However, flattening of the foot plate and subsequent semi flattening of the leg segment establish preaxial and postaxial borders. The bud then rotates about 90 degrees medially. The preaxial border (which is cranial in position before rotation) becomes medial, thus bringing the big toe to the medial border of the foot. The extensor muscles (originally on the dorsal aspect) become anterior and the flexor muscles (originally on the ventral aspect) posterior. Only in the gluteal region, the original dorsal aspect remains dorsal. As a result of this rotation, the lower limb undergoes spiralling. Except for the medial rotation, rest of the development like formation of car ilage models, inter zone modification into joint spaces and ossification are similar to the upper limb bud. The lower imb arises opposite the lower 4 lumbar and upper 2 sacral segments and so the lower limb muscles derive their nerve supply from these segments.

Consequent to the medial rotation of the bud, the following features occur:

- Flexion of knee and flexion of ankle (plantar flexion) bring the (adult) posterior surfaces closer to each other;
- Dorsi flexion of ankle is actually extension;
- The dermatomes of the skin of the lower limb follow the rotation and spiraling.
- The two thighs converge towards each other; the distal parts of the lower limbs lie parallel to each other; these make the line of gravity fall within a smaller base thus facilitating erect posture and powerful gait.

FASCIAE OF LOWER LIMB

Superficial Fascia

The superficial fascia is deep to the skin and consists of connective tissue that has a variable amount of fat, cutaneous nerves, superficial veins, lymphatic vessels and lymphatic nodes. The superficial fascia in the upper part of the front of the thigh consists of two layers.

- There is a ***superficial fatty layer*** and a ***deep membranous layer***. These two layers are continuous with the corresponding layers of the superficial fascia of the anterior abdominal wall, in front of the inguinal ligament. At the knee, the superficial fascia loses its fat and blends with the deep fascia. However, the superficial fascia regains some fat in the leg.

Deep Fascia

The deep fascia of the lower limb is strong and invests the limb like a close fitting elastic stocking. When muscles contract, they expand in size. Outward expansion of the muscles is prevented by the deep fascia; muscular contraction then compresses the veins facilitating venous return to the heart.

The deep fascia of the thigh is called the ***fascia lata***. Since it encloses the thigh as a sleeve, both its superior and inferior attachments are circular. The membranous layer of the superficial fascia attaches to the fascia lata about two fingers' breadth below the inguinal ligament. The fascia lata continues, on the posterior aspect of the knee, as the popliteal fascia. Along the lateral aspect of the thigh, the fascia lata is thickened and forms a strong band passing from the anterior part of the iliac crest to the lateral condyle of the tibia. This band is, therefore, called the ***ilio-tibial tract***. This broad band is the shared aponeurosis of tensor fascia latae and the gluteus maximus muscles.

Around the knee, the deep fascia of thigh is continuous with the deep fascia of leg Also called the crural fascia (Latin. crus=leg), the deep fascia of leg is thick in the upper part of the anterior aspect of the leg. Though it is thinner distally, it thickens to form the extensor, peroneal and flexor retinacula around the ankle.

CUTANEOUS INNERVATION OF LOWER LIMB

Cutaneous innervation of the lower limb can be studied under six areas, namely:

- Front of thigh
- Gluteal region
- Back of thigh
- Front of leg and dorsum of foot
- Back of leg and
- Sole of foot

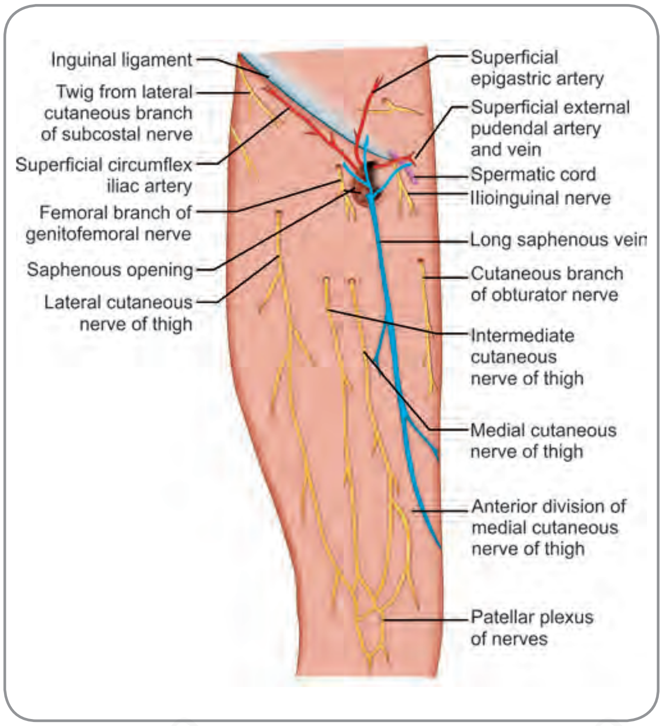


Fig. 21.3: Superficial veins and nerves seen on the front of thigh

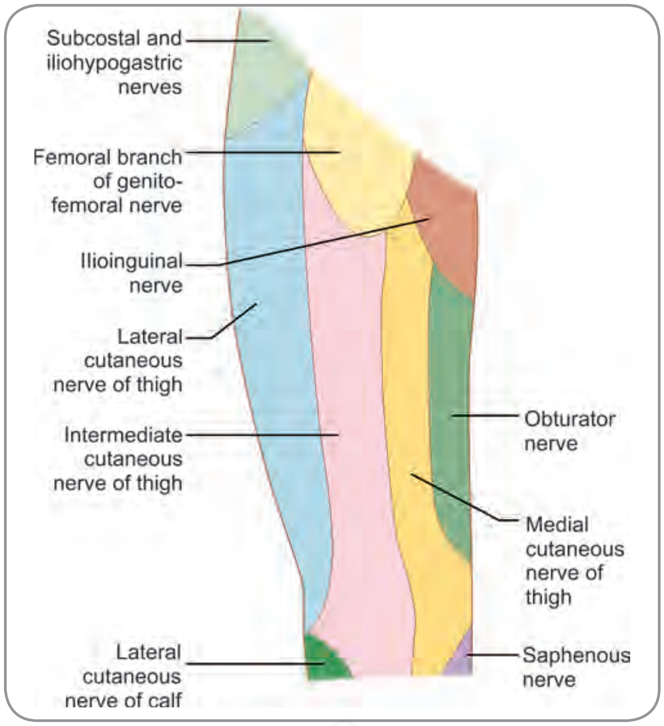


Fig. 21.4: Cutaneous nerve supply of the front of thigh

Dissection

With the cadaver in supine position, palpate the following structures:

- Pubic tubercle, anterior superior iliac spine and iliac crest;
- Patella and femoral condyles;
- Tibial condyles;
- Malleoli.

As each region of the lower limb is being dissected, see and study the superficial veins, the cutaneous nerves and the fasciae of the region.

Utilise all opportunities to see and study the following:

- Dorsal venous arch
- Great and small saphenous veins
- Sural nerve
- Posterior cutaneous nerve and
- Lateral cutaneous nerve of thigh (Fig. 21.3).

A. Front of Thigh (Fig. 21.4)

Cutaneous innervation of the front of thigh appears to be in four longitudinal strips and from lateral to medial, these are supplied by the ***lateral cutaneous nerve of thigh***, the ***intermediate cutaneous nerve of thigh***, the ***medial cutaneous nerve of thigh*** and the ***cutaneous branches of the obturator nerve***. Superior to these and immediately below the inguinal ligament, three areas of cutaneous distribution can be defined; these three, from lateral to medial, are supplied by the ***subcostal*** and ***iliohypogastric*** nerves, the ***femoral branch of the genitofemoral nerve***, and the ***ilioinguinal nerve***.

In the region of the knee, a small area on the lateral aspect is innervated by the ***lateral cutaneous nerve of the calf***, and a similar small area on the medial aspect by the ***saphenous nerve***. Small twigs from the ***lateral cutaneous nerve of thigh***, ***intermediate cutaneous nerve of thigh***, ***medial cutaneous nerve of thigh*** and the ***saphenous nerve*** join up on the anterior aspect of the knee and form the ***patellar plexus*** (Fig. 21.3).

B. Gluteal Region (Fig. 21.5)

Though the predominant nerve supply of the entire lower limb is through ***ventral rami*** of spinal nerves, some areas

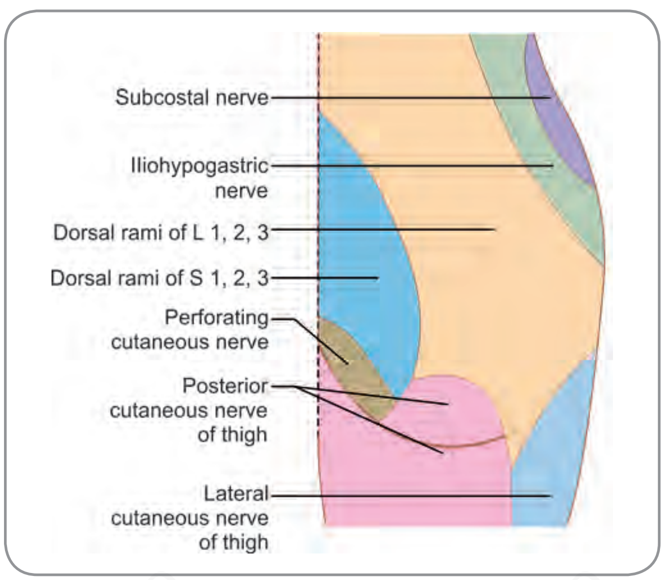


Fig. 21.5: Cutaneous nerve supply of the gluteal region

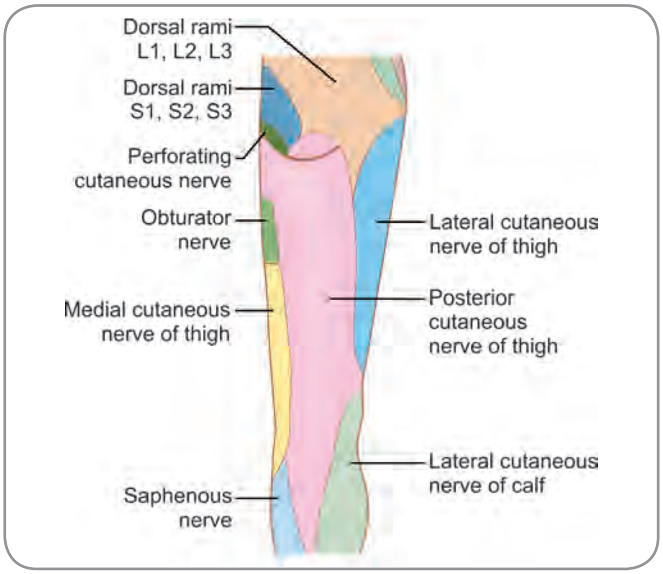


Fig. 21.6: Cutaneous nerve supply of the back of thigh

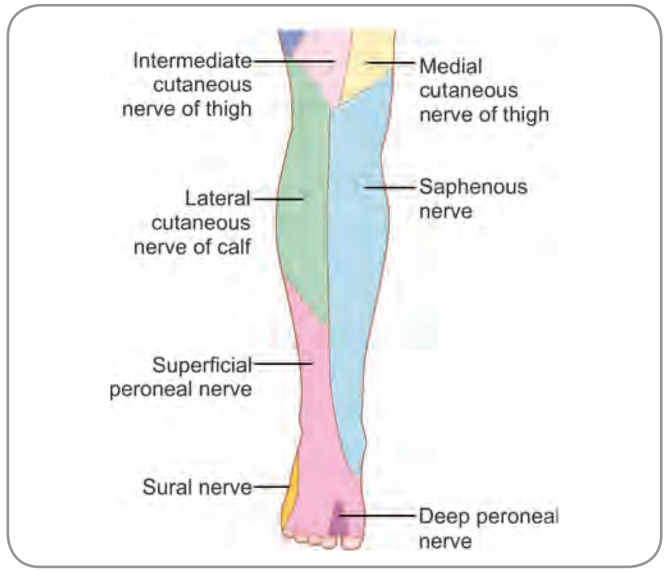


Fig. 21.7: Cutaneous nerve supply of the front of leg and the dorsum of foot

of skin over the gluteal region are supplied by ***dorsal rami***. It is customary to divide the gluteal region into four quadrants and then describe the cutaneous innervations. The superomedial quadrant is supplied by branches from the dorsal rami of spinal nerves S1, 2, 3 and L1, 2, 3

All other quadrants are innervated by nerves derived from ventral rami. The superolateral quadrant is supplied by he lateral cutaneous branches of the ***subcostal*** and the ***iliohypogastric nerves***. These branches may supply the skin as low as the level of greater trochanter. The inferolateral quadrant receives a branch from the ***lateral cutaneous nerve of thigh***. The inferomedial quadrant is supplied by the ***perforating cutaneous nerve***, near the midline, and by the gluteal branches of the ***posterior cutaneous nerve of thigh***, more laterally.

C. Back of Thigh (Fig. 21.6)

Most of the back of thigh is innervated by the ***posterior cutaneous nerve of thigh***. This nerve also supplies the upper part of the back of the leg. The lateral and medial aspects of back of thigh are supplied by nerves which also supply the front of thigh. Thus, a small strip on the upper part of the medial border is supplied by branches of the ***obturator nerve*** and the lower part of the medial border is supplied by twigs from the ***medial cutaneous nerve of thigh***. The areas adjacent to the lateral border are supplied by twigs from the ***lateral cutaneous nerve of thigh***.

Near the knee, the lower part of the back of thigh receives branches from the *saphenous nerve* (medially) and from the *lateral cutaneous nerve of calf* (laterally) (Fig. 21.6).

D. Front of Leg and Dorsum of Foot (Fig. 21.7)

The front of leg is conveniently described in two parts, namely the upper and the lower parts

- The upper part is supplied by branches of the ***saphenous nerve*** medially and the ***lateral cutaneous nerve*** of calf laterally.
- The lower part receives branches from the ***saphenous nerve*** medially and the ***superficial peroneal nerve*** laterally.

The dorsum is also subdivided into three parts, namely the medial part (the medial border and a small strip adjacent to it), the lateral part (the lateral border and a small adjacent area) and the intermediate part.

- The intermediate part, making up a major portion of the dorsum is supplied by branches of the ***superficial peroneal nerve***.
- The medial part is supplied by the ***saphenous nerve*** (upto the base of the great toe)
- The lateral part is supplied by the sural nerve.
- The skin of the web between the great and the second toes is supplied by the deep peroneal nerve.

Innervation of the skin of the dorsal aspects of the toes is important and is by as many as four nerves. The lateral side of the little toe is supplied by the sural nerve. The remaining parts of the toes are supplied by branches of the superficial peroneal nerve. The nail beds of the medial three-and-a half toes receive supply from the medial plantar nerve and of the lateral one-and-a-half toes from the lateral plantar nerve.

E. Back of Leg (Fig. 21.8)

The back of leg can be subdivided into an upper part and a lower part for description of its cutaneous innervation.

- The medial aspect of the upper part is supplied by branches of the ***saphenous nerve***, the middle aspect by branches of the ***posterior cutaneous of thigh*** and the lateral aspect by branches of the ***lateral cutaneous nerve of calf***

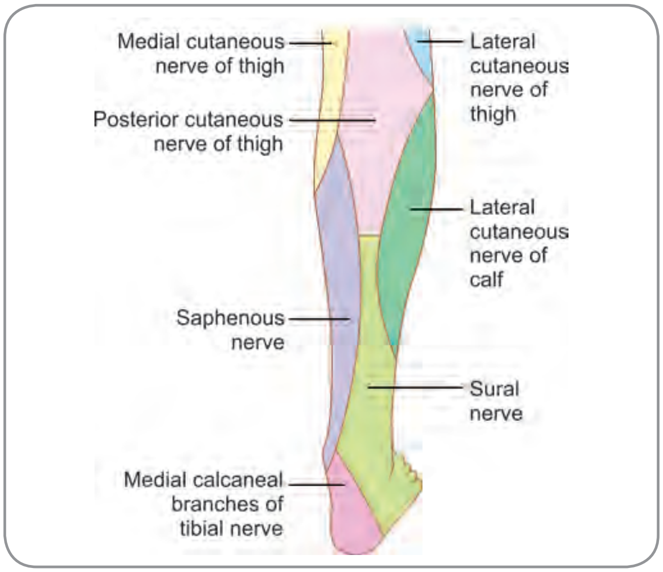


Fig. 21.8: Cutaneous nerve supply of the back of leg

- The medial aspect of the lower part receives twigs from the ***saphenous nerve*** and the middle and lateral aspects from the ***sural nerve***.
- The skin over the heel is supplied by ***medial calcaneal branches*** of the tibial nerve.

F. Sole

The anterior part of the skin of the sole, including the medial 3½ digits, is supplied by the ***medial plantar nerve***. The lateral part, including the lateral 1½ digits is supplied by twigs of the ***lateral plantar nerve***.

As mentioned above, branches from these nerves also supply the dorsal aspect of the terminal parts of the toes including the nail beds. A strip of skin along the lateral margin of the sole, reaching up to the lateral surface of the little toe is supplied by the sural nerve. On the medial side, a strip is supplied by the saphenous nerve; however, this strip does not reach the big toe. Skin over the heel is supplied by the medial calcaneal branches of the tibial nerve.

Added Information

- The LCN of thigh, ICN of thigh, MCN of thigh and the saphenous nerve are branches of the femoral nerve; they pierce the deep fascia and reach the subcutaneous plane along an oblique line that is roughly the superomedial border of Sartorius.
- The skin overlying the femoral triangle is supplied by the ilio-inguinal nerve and the femoral branch of the genitofemoral nerve.

Dermatomal Map of the Lower Limb

De matome is the area of skin supplied by one ventral ramus (the ventral ramus of one spinal nerve) through its various cutaneous branches (Fig 21.9).

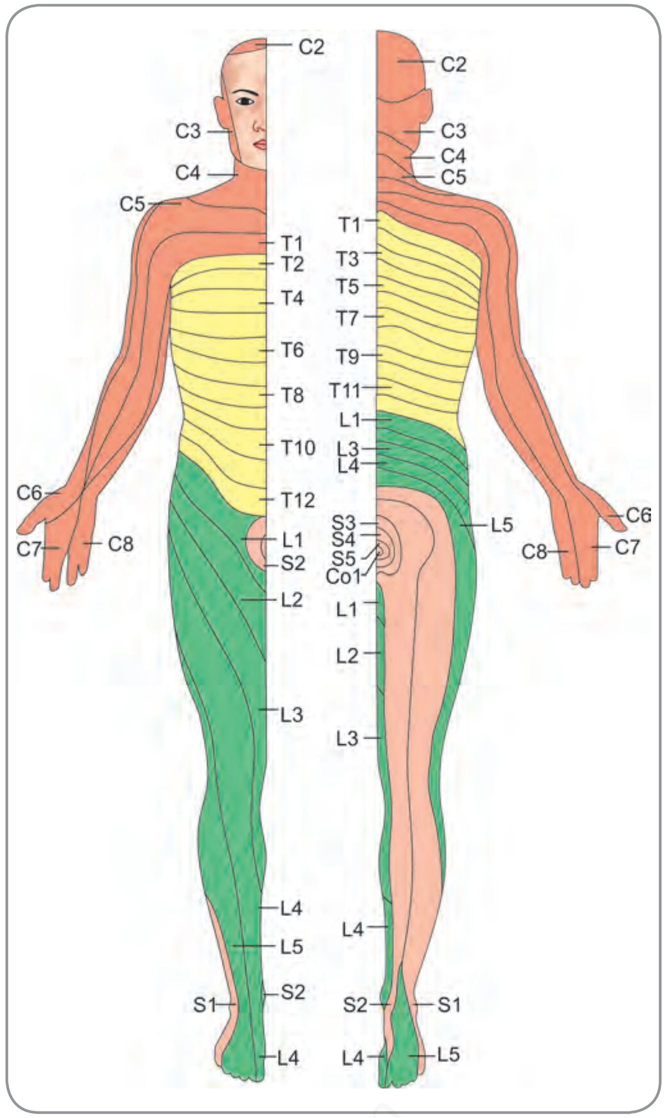


Fig. 21.9: Dermatomes—strips of skin supplied by the various levels or segments of the spinal cord

The dermatomal map of the lower limb can easily be drawn if the development of the lower limb bud is properly understood. The lower limb bud appears opposite the L1 to S3 segments of the spinal cord in the 5th week of intrauterine life. As the bud develops and elongates, it drags the corresponding dermatomes and the spinal nerves. Therefore, the dermatomal map involves L1 to S3.

The distal part of the lower limb bud gets flattened into a foot plate. The bud has a central axis, a pre-axial border and a post-axial border. Initially, the great toe which is on the pre-axial border, is also on the cranial aspect of the developing foot plate. The limb bud subsequently undergoes rotation during its development. The preaxial border curves medially and the pre-axial digit (great toe) occupies the medial aspect. As a corollary, the post-axial border curves laterally and the post-axial digit (little toe)

occupies the lateral aspect. The dorsal surface (except for he gluteal region) becomes anterior and the ventral surface becomes posterior. The pre-axial border starts, as superimposed on the adult limb, from the middle of thigh and runs to the knee; it curves medially and descends to the medial malleolus; it then runs along the medial border of the foot to reach the great toe.

The dermatomal boundary lines can be seen to follow the developmental outcome. They reflect the elongation and spiralling of the limb bud. The lumbar dermatomes L1 to L3 lie one below the other on the front of the limb, till below the knee and curving medially. L4 occupies the medial aspect of the leg and the medial side of the foot including the big toe; L5 occupies the lateral aspect of the front of leg and the medial aspect of the dorsum including the medial three toes.

The S1 dermatome starts on the lateral aspect of the dorsum and the sole including the little toe. It ascends up on the back of leg till the middle. From the level of the middle of the leg, S2 ascends till the gluteal fold. S3 occupies the medial aspect of the gluteal region. L1 and 2 dermatomal area extends around the lateral aspect of the upper thigh to the posterior aspect (Fig 21.10).

Added Information

- The dermatomal map of the lower limb, as given above, is the one mapped by Foerster in 1933. This is the map preferred by many clinicians due to its correlation with clinical findings. There is yet another mapping given by Keegan and Garrett in 1948 which has a better symmetry and better correlation with development.

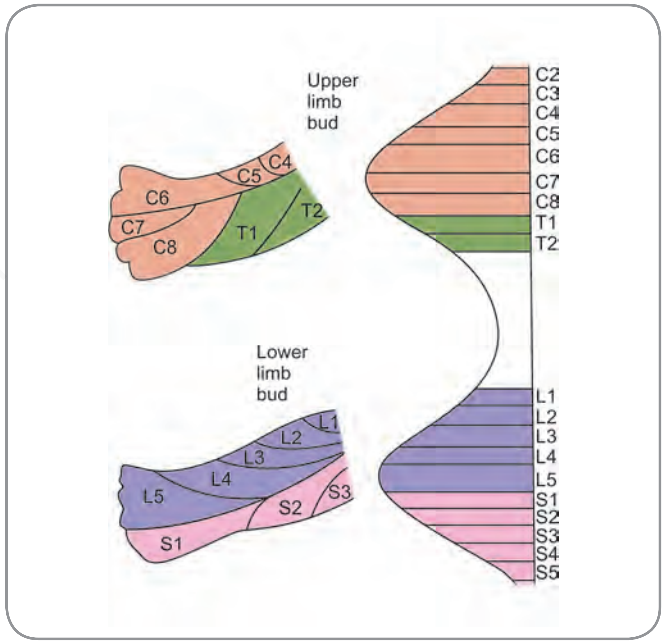


Fig. 21.10: Arrangement of dermatomes in the upper and lower limbs of the embryo

VEINS OF LOWER LIMB (FIG. 21.11)

The veins of the lower limb can be divided into ***deep*** and ***superficial*** veins (like those of the upper limbs) The superficial veins, which run in the subcutaneous fascia, are independent of the named arteries. Many of them can be seen through the skin. The deep veins are deep to the deep fascia and accompany all major arteries.

Both the superficial and the deep veins have valves; however, the valves are more numerous in the deep veins. The superficial veins drain into deep veins at their termination. They are also connected to deep veins through ***perforating*** veins that pass through deep fascia.

Superficial Veins of the Lower Limb

In many individuals, several veins can be seen through the skin in the lower limb. Many of them appear to be connected to each other. The two major superficial veins are the great saphenous vein and the small saphenous vein (Fig. 21.12).

To study the superficial veins, it is necessary to know some basic facts about the veins of the foot. On the dorsum of the foot, a ***dorsal venous arch*** is found (Fig. 21.11). Located on the distal aspects of the metatarsal bones, the arch receives the ***dorsal digital*** and the ***dorsal metatarsal veins*** on its distal convex aspect. Proximal to the arch and lying in its concavity is the ***dorsal venous plexus***, which also communicates with the arch. The arch curves proximally; the medial end of the arch is joined by the ***dorsal digital***

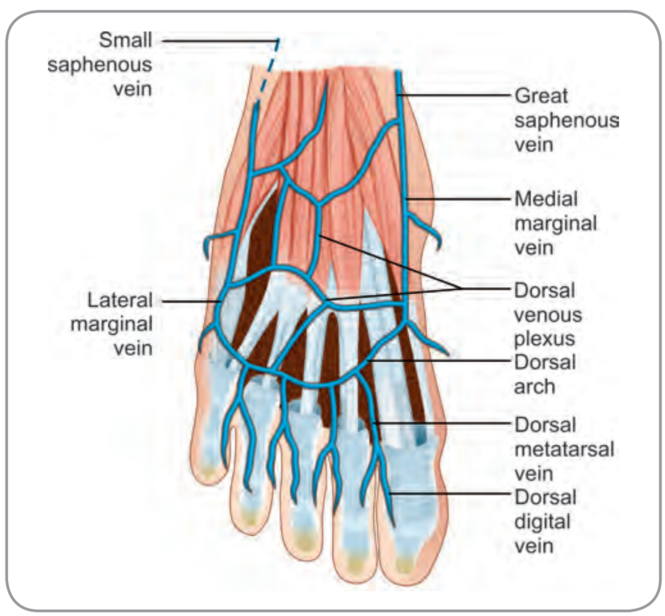


Fig. 21.11: Veins on the dorsum of foot

vein of the big toe to form the ***medial marginal vein***; the lateral end of the arch is joined by the dorsal digital vein of the little toe to form the ***lateral marginal vein***. These two veins run along the corresponding borders of the foot, communicate with both the plantar and dorsal venous networks and drain both surfaces of the respective borders into the dorsal venous arch.

The medial marginal vein contributes to the formation of the great saphenous vein and the lateral marginal vein to the formation of the small saphenous vein.

Great Saphenous Vein

The ***great saphenous vein***, also called the ***long saphenous vein*** (Greek 'Saphene'=clearly visible; also Arabic 'Safin'=standing) and the ***vena saphena magna***, is a continuation of the medial marginal vein (Fig. 21.11). It ascends up the leg, a little in front of the medial malleolus and lies for some distance on the medial surface of the tibia. Ascending up on the medial side of the leg, it crosses the medial side of the knee joint, about 2 to 3 fingers' breadth posterior to the medial border of the patella.

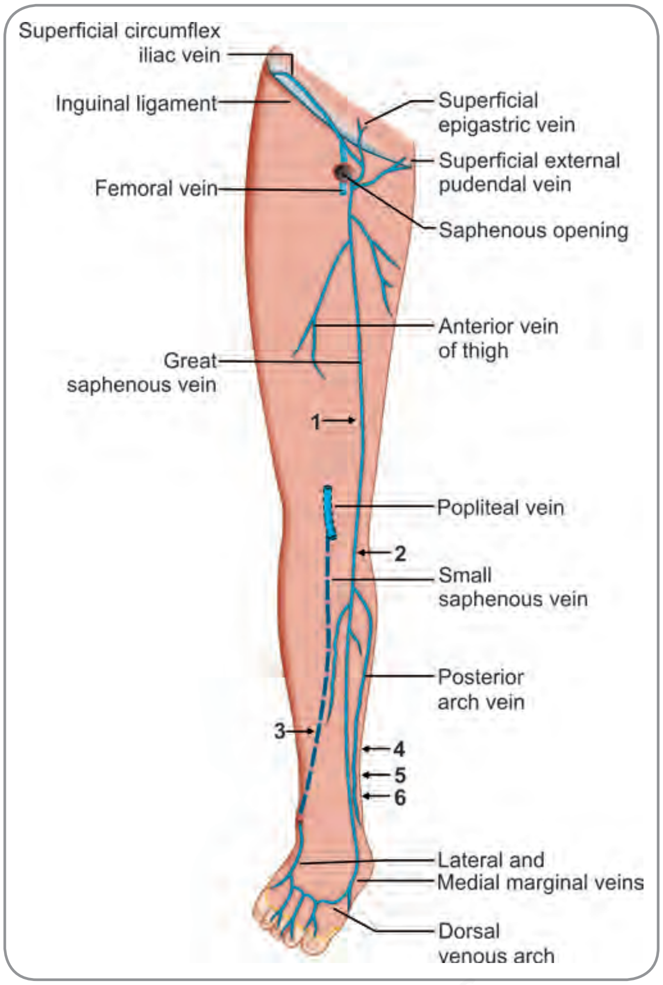


Fig. 21.12: Superficial veins of lower limb. Numbered arrows (from 1 to 6) indicate the position of perforating veins

It then ascends on the medial side of the thigh. In the upper part of the thigh, it curves a little laterally, pierces the cribriform fascia and passes through ***the saphenous opening*** in the deep fascia to end in the femoral vein. The great saphenous vein is the longest vein in the body.

The great saphenous vein receives numerous tributaries from the front and back of leg, and from the front of thigh. As it ascends in the leg and thigh, it also receives several communicating veins from the small saphenous vein at several locations. Just below the knee it receives the ***anterior vein of the leg*** and the ***posterior arch vein*** (a vein which is formed near the medial malleolus and ascends up the medial side of leg to reach the knee area). The tributaries from the medial and posterior aspects of thigh frequently unite to form an ***accessory saphenous vein***, which drains into the great saphenous vein. When present, this vein becomes the major communicating vein between the great and the small saphenous systems.

Just before it pierces the deep fascia, the great saphenous vein receives the superficial epigastric, superficial circumflex iliac and (superficial) external pudendal veins (collectively called the peri-inguinal veins) These veins accompany the corresponding arteries. It also receives the ***anterior cutaneous vein of thigh*** which drains the lower part of the front of thigh and the ***lateral cutaneous vein of thigh*** which drains the lower part of the lateral aspect of thigh. Before piercing the femoral sheath, the great saphenous vein also receives the deep external pudendal vein.

The great saphenous vein is connected to the deep veins of the leg and the thigh through a number of ***perforating veins***. It is accompanied by the saphenous nerve in the leg, the descending genicular artery at the knee region and the branches of medial cutaneous nerve of thigh above the knee.

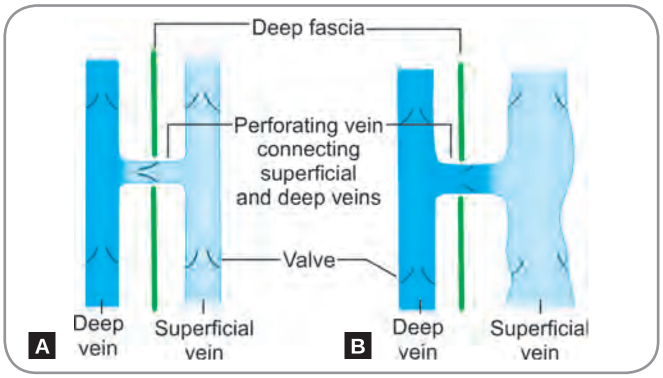
Small Saphenous Vein

The ***small saphenous vein***, also called the **short saphenous vein** and the **vena saphena parva**, is a continuation of the lateral marginal vein. Ascending behind the lateral malleolus and along the lateral border of the tendocalcaneus, it runs further upwards along the middle of the back of the leg. Running between the two heads of gastrocnemius, it reaches the popliteal fossa, where it pierces the deep fascia and ends in the popliteal vein.

Along its course, it receives several tributaries from the front and back of leg.

Perforating Veins (Figs 21.12 and 21.13A and B)

The perforating veins, or simply the perforators, are so called, as they perforate the deep fascia to connect the superficial veins to the deep veins. Valves in them allow blood flow from superficial to deep veins, but not in the reverse direction. They pass through the deep fascia at an oblique angle so that when the muscles contract and pressure increases within the deep fascia, they are compressed. Compression prevents deep to superficial flow.



Figs 21 13A and B: Scheme to show the role of perforating veins. **A.** Normally blood flows only from superficial to deep veins **B.** When the valves in perforating veins become incompetent blood flows from deep to superficial veins leading to distension of the latter

The sites at which perforators are present in the lower limb are variable. Some common sites of perforators are:

- Lower part of the adductor canal, where a perforator (the Dodd's perforator or the Hunterian perforator) connects the great saphenous vein to the femoral vein;
- Just below the knee, where a perforator (Boyd's perforator or the tubercle perforator) connects the great saphenous vein to the posterior tibial veins.

A variable site is present on the lateral aspect of the leg, where a perforator connects the small saphenous vein to the posterior tibial veins.

The posterior arch vein is connected to the anterior tibial veins by three perforators which are present between the level of medial malleolus and the mid-calf. These are called the Cockett's perforators

Deep Veins of Lower Limb

The deep veins of the lower limb accompany all the major arteries and their branches. However, these are not single veins along a single artery. They are paired veins, which flank the artery on either side and interconnect frequently with each other. Called the venae comitantes (Latin 'comitante'=accompanying), they, along with the artery, are usually contained within a connective sheath; the presence of the artery and the venae comitantes in a single vascular connective sheath is advantageous to venous return; the pulsations of the artery compress the veins and help blood flow in the latter. The veins accompanying the femoral and the popliteal arteries are single and are called by the same name.

The deep veins of the lower limb (from the periphery to the centre) are:

- The digital veins,
- The metatarsal veins,
- The medial and lateral plantar veins (Deep veins of the sole),
- The posterior tibial and the fibular veins,
- The anterior tibial veins,
- The popliteal vein and
- The femoral vein.

Few perforating veins from the dorsal venous plexus and the dorsal venous arch pierce the deep fascia and connect to the anterior tibial veins (the venae comitantes of the anterior tibial artery) in the anterior compartment of leg. The medial and lateral plantar veins of the deeper aspect of the sole form the posterior tibial and fibular veins behind the medial and the lateral malleoli respectively.

Venous Return from the Lower Limb

Venous blood from the lower limbs has to ascend to the heart against gravity. This ascent depends on the following factors.

- The ***atmospheric pressure*** within the thoracic cavity is negative and this tends to suck blood in the venous system towards the heart.
- The veins of the lower limb are provided with ***numerous valves*** along their course. The valves, when competent, allow blood flow only towards the heart.
- The leg and thigh are enclosed in a tight sleeve of ***deep fascia***. The deep veins lie within the sleeve, along with arteries and muscles. The superficial veins lie outside the sleeve. Perforators penetrate the sleeve. When muscles contract, they increase in size, thus raising the pressure within the sleeve. This pressure compresses the deep veins and because of the presence of valves, blood is pushed towards the heart.
- The soleus muscle has many ***venous sinuses***. When the muscle contracts, blood is squeezed out into the deep veins, aiding venous return.
- Venous return through deep veins is also aided by pulsations of adjoining arteries.

Added Information

- The great saphenous vein has about 10 to 12 valves along its course; valves are more in number in the leg than in the thigh
- To end in the femoral vein, the great saphenous vein pierces the anterior wall of the femoral sheath.
- A venous valve guards the sapheno-femoral junction.
- The superficial to deep pattern of blood flow is important; muscular contractions cause blood to flow from perforators to deep veins and from deep veins toward the heart; a musculovenous pump is thus set in work and venous return to the heart is enhanced.
- The posterior arch vein is often referred to as the ***'Vein of Leonardo da Vinci'*** and is connected to the anterior tibial veins through perforators.
- The anterior and the lateral cutaneous veins of thigh may often be seen as one single anterolateral cutaneous vein of thigh.
- When a prominent vein draining the lower part of the medial aspect of thigh ascends up to drain into the great saphenous vein, it is referred to as the posteromedial cutaneous vein of thigh.
- Superficial epigastric vein communicates with the lateral thoracic veins through the thoracoepigastric vein. This establishes a communication between the inferior and superior vena caval territories.

Clinical Correlation

- In emergencies when superficial veins in other parts of the body are collapsed and not visible, the great saphenous vein is chosen for doing ***venous cut-downs***. The vein is usually exposed just in front of the medial malleolus and cannulated. Saphenous cut downs are also used in obese individuals and in infants.
- Injury to the saphenous nerve may occur during ***saphenous cut-downs***. Numbness or pain along the medial border of the foot occurs.
- Segments taken from the great saphenous vein are used as ***grafts in coronary bypass surgery*** (i.e., for replacing a blocked segment of a coronary artery). Segments can also be used for bypass operations at other sites. Ready accessibility of the vein, sufficient distance of the vein between tributaries, thus allowing usable lengths to be harvested and a higher percentage of muscular and elastic tissue in its walls than other veins are the anatomical causes facilitating the graft procedure. In such operations, the direction of the segment is reversed, so that valves do not interfere with blood flow.
- ***Varicosity of veins*** is a condition where the superficial veins are dilated and tortuous. This condition is seen in people who stand for long hours. Policemen, nurses and surgeons may get affected. Prolonged standing leads to compromise of the muscular mechanism of venous blood pump and the valves become incompetent gradually. The latter factor causes reversal of blood flow and the superficial veins get dilated. Varicose veins are common in the posteromedial aspects of the lower limb.
- ***Thrombophlebitis*** (inflammation of veins) of the superficial veins may complicate varicosity. Pain, swelling, redness and dryness of the affected area can be seen. Venous stasis occurs and the reduced oxygen level causes ulcers (venous ulcers).
- ***Deep vein thrombosis (DVT;*** also called ***phlebothrombosis)*** is a dangerous condition associated with prolonged immobilization of the individual. When there is nil or minimal activity in the lower limbs, venous stasis occurs leading to thrombosis The thrombus may dislodge and form an embolus, which may find its way to the heart through the venous circulation or from the heart to the lungs through the pulmonary circulation. If pulmonary embolism occurs, it is fatal. Immobilization due to prolonged hospital stay, long drawn use of plaster casts or bandage of the lower limbs, muscular inactivity due to long distance air travel are the commonly seen causes of DVT.

LYMPH NODES AND LYMPHATIC DRAINAGE OF LOWER LIMB

Lymph Nodes

The lymph nodes of the lower limb can be described in two groups, namely the ***superficial*** and the ***deep groups***.

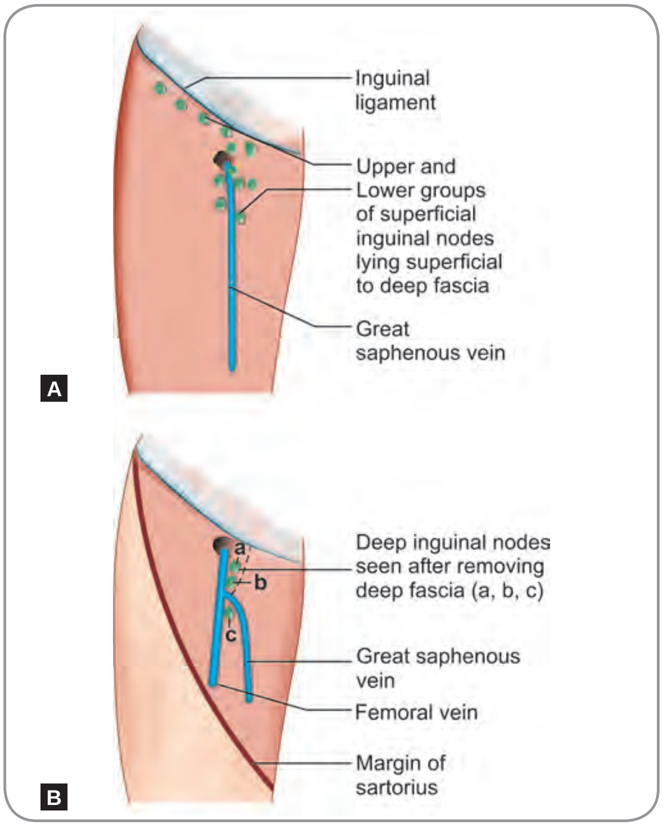
The superficial group comprises the superficial inguinal nodes which are present in the superficial fascia of the inguinal region. They can further be divided into the horizontal and the vertical subgroups (Fig. 21.13A).

The nodes of the horizontal sub-group are horizontally disposed and lie below and parallel to the inguinal ligament. The medial nodes of this group receive lymph from parts of the external genitalia, parts of pelvic organs and medial part of the anterior abdominal wall below the umbilicus. The lateral nodes of this group receive lymph from the gluteal region, most of the lower limb and the lateral part of the anterior abdominal wall below the umbilicus (Fig. 21.14).

The nodes of the vertical subgroup are vertically disposed and lie along the terminal portion of the great saphenous vein. They receive all the superficial lymph vessels of the lower limb which run along the superficial veins (Fig. 21.14).

The deep group of lymph nodes comprises the deep inguinal nodes and the popliteal lymph nodes.

The deep inguinal nodes are present deep to the deep fascia and are found in the upper part of the femoral triangle on the medial aspect of the femoral vein (Fig.



Figs 21.14A and B: Inguinal lymph nodes—**A.** Superficial group **B.** Deep group

21.14B). One of these nodes is located in the femoral canal and is called the node of Cloquet. The ***node of Cloquet*** receives lymph from the glans penis in the male and the clitoris in the female. The rest of the deep inguinal nodes receive lymph from the deeper parts of the thigh, the popliteal lymph nodes and the superficial group of lymph nodes. The efferents from these nodes go to the external iliac nodes.

The ***popliteal lymph nodes*** are found in the fat of the popliteal fossa. Numbering about four to six, these nodes lie in three sets. The first set is the superficial most and lies at the saphenopopliteal junction (the point where small saphenous vein enters the popliteal vein) The second set, which is the intermediate set, lies along the popliteal vessels. The third set is the deepest and lies on the posterior aspect of the knee joint deeper to the popliteal artery.

Superficial lymphatic vessels which accompany the small popliteal vein (carrying lymph from the lateral parts of foot heel and lateral part of back of leg) drain into the superficial set. Deep lymph vessels accompanying the anterior and posterior tibial vessels (carrying lymph from all parts of foot and leg) drain into the intermediate set. Lymph from the knee joint drains into the deep set.

Efferents from all sets of the popliteal nodes go to the deep inguinal nodes (Fig. 21.15).

Efferent lymph vessels from the deep inguinal nodes go to the external and common iliac nodes; and the efferents from these nodes enter the lumbar lymphatic vessels.

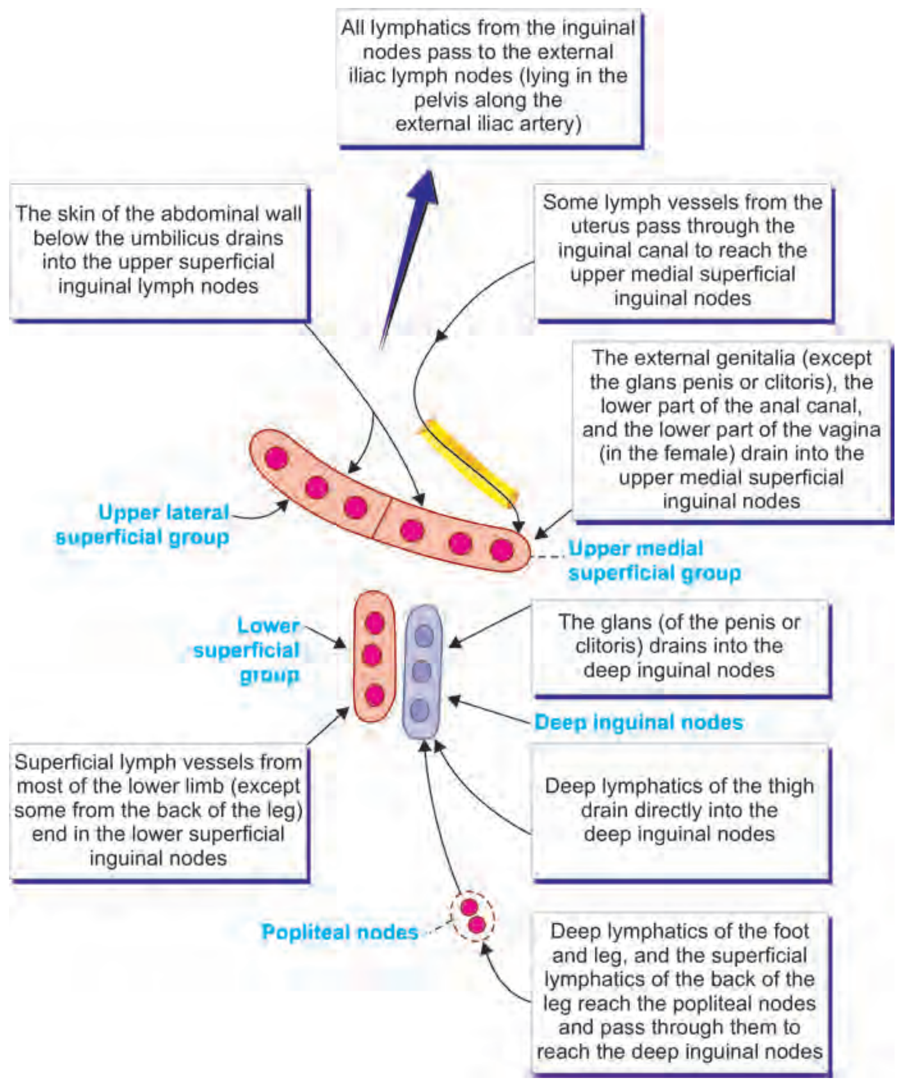


Fig. 21.15: Scheme to show areas drained by the inguinal lymph nodes

Overall Lymphatic Drainage of the Lower Limb

All the superficial lymphatic vessels of the lower limb converge towards either of the saphenous veins and accompany both of them. The lymphatics accompanying the great saphenous vein drain into the vertical group of the superficial inguinal nodes. Most of the efferents from this group pass to the external iliac nodes (located along the external iliac vein) and the remaining few to the deep inguinal nodes. The lymphatics accompanying the small saphenous vein drain into the popliteal nodes and the efferents pass to the deep inguinal nodes.

Deep lymphatic vessels of the foot and the leg accompany the deep veins and drain into the popliteal nodes. Deep lymphatics of thigh drain into the deep inguinal nodes.

Clinical Correlation

Inguinal lymph nodes show lymphadenopathy in diseases involving the lower part of the trunk, perineum and the entire lower limb. A few lymphatics from the uterine fundus drain into the superficial inguinal lymph nodes; so, possibility of metastasis in uterine cancers should be thought of in cases of inguinal lymphadenopathy in female patients.

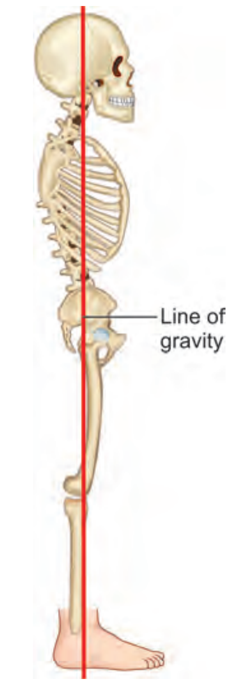


Fig. 21.16: The line of gravity

MOTOR ACTIVITIES OF LOWER LIMB

The primary function of the lower limbs is to facilitate standing and walking. Various muscles of the lower limb act in unison to produce various movements required for these positions. The bones of the lower limb are also suitably adapted to bear and transmit weight of the body.

Stability and strength are the characteristic features of the lower limbs. While standing, the centre of gravity falls between the two heads of femora (approximately at the middle of the body of the last lumbar vertebra); the line of gravity, from above downwards, passes through the dens of axis (cervical vertebra), in front of sacral promontory, behind the centre of hip joint and in front of knee and ankle joints. Weight of the body is transmitted from the sacrum to the ilia through the sacroiliac joints and then through the femora and tibia to the arches of feet. In each foot, the talus bone distributes the body weight backward through the calcaneus to the heel and forward through the tarsus and metatarsus to the ball of the toes.

When a person is standing only a few of the lower limb muscles are acting. The joints are also so disposed that only a minimal muscular activity is required to prevent the individual from falling down. In normal standing (frequently, the stand-easy position), both the hip and the knee are stable; they both are extended, their articular surfaces are in maximal contact and their ligaments taut. Weight transfer is therefore easy.

The ankle is however less stable. The ***line of gravity*** (Fig. 21.16) passes between the two limbs and anterior to the axis of rotation of the ankle joints. As a result of this, there is a tendency to sway and fall forward. This forward sway has to be countered by periodic contraction of the calf plantar flexors When the muscles are fatigued, forward sway is rapid

Lateral stability is increased by keeping the legs apart (splay of feet). However, this can cause lateral sway which is counterbalanced by the hip abductors.

It is necessary to note that in the balanced, erect position, the only detectable activity in the lower limb muscles, is in the muscles of the calf.

The muscles and tendons of the sole have the most important function of maintaining the arches of the feet both during standing and locomotion.

Myotomal Map of the Lower Limb (Table 21.2)

The muscle mass that receives Innervation from a single spinal cord segment or spinal nerve is called a myotome. Though embryologically this would have been a single muscle mass, it may be separated into more number of muscles in the adult.

In the limb muscles, yet another modification is noticed. Each of these muscles receives motor fibres from several spinal cord segments or nerves. Thus, most muscles of the lower limb are composed of more than one myotome.

Similarly, movements of the lower limb are produced by multiple spinal segments.

Table 21.2: Myotomal map of lower limb

Joint	Movements	Spinal segments involved
Hip	Flexion	L2,3
	Extension	L4,5
	Medial Rotation	L1,2,3
	Lateral Rotation	L5, S1
	Adduction	L1,2,3,4
	Abduction	L5, S1
Knee	Flexion	L5, S1
	Extension	L3,4
Ankle	Dorsiflexion	L4,5
	Plantarflexion	S1,2
Subtalar	Inversion	L4 5
	Eversion	L5, S1
MP and IP	Dorsiflexion of toes	L5, S1
	Plantarflexion of toes	S1,2

Multiple Choice Questions

1. Which nerve contributes twigs to the patellar plexus?
   a. Genitofemoral nerve
   b. Iliohypogastric nerve
   c Sural nerve
   d. Saphenous nerve

2. The vein formed near the medial malleolus and ascending up the medial side of leg is:
   a. Posterior arch vein
   b. Medial arch vein
   c. Short saphenous vein
   d. Accessory saphenous vein

3. Perforators perforate the:
   a. Superficial fascia
   b. Superficial veins
   c. Deep fascia
   d. Deep veins

4. Efferents from popliteal lymph nodes go to:
   a. External iliac nodes
   b. Deep inguinal nodes
   c. Vertical sub-group of inguinal nodes
   d. Medial nodes of horizontal sub-group

5. Normal line of gravity causes a:
   a Forward sway
   b. Backward sway
   c. Left sway
   d. Right sway

ANSWERS

1. d **2.** a **3.** c **4.** b **5.** a

Clinical Problem-solving

Case Study 1: A young man had a street injury on his leg. He neglected it for many days in spite of having some pain. Days later, he developed a few small-sized swellings at the back of his knee which he thought was a little more painful. Few days from that, he also developed a few more swellings in his groin.

- Which structure(s) was/were causing swelling at the groin?
- Similarly, what was causing the swelling in the popliteal fossa?
- Why did the swelling appear in the popliteal region first and then in the inguinal region?

Case Study 2: A 54-year-old man suffered a heart attack. His physician convinced him on the need for a coronary bypass surgery. As the patient agreed to the procedure, he found the medical team was examining his lower limbs and cleaning them up.

- Can you suggest the reason for the lower limbs to be examined?
- Why is the great saphenous vein preferred for this procedure?
- Will not the venous valves of the great saphenous vein cause problem during grafting?

(For solutions see Appendix).

Chapter 22

Bones of Lower Limb

Frequently Asked Questions

- Describe (a) The lower end of femur, (b) The upper end of femur.
- Describe any one of the following: (a) Fibula, (b) Calcaneum, (c) Cuneiform, (d) Navicular.
- Write notes on (a) Sustentaculum tali, (b) Gluteal tuberosity, (c) Linea aspera, (d) Intercondylar area of tibia, (e) Femoral torsion, (f) Neck-shaft angle of femur, (g) Greater sciatic notch and foramen, (h) Obturator foramen.
- What is the subpubic angle and what is its functional significance.
- Write notes on (a) Intertrochante ic line and crest, (b) Patella.

The bony skeleton of the lower limb is connected to the vertebral column by the pelvic girdle. The girdle, in turn, is formed by the hip bone on either side and the sacrum and coccyx in the middle posteriorly. The skeleton of the pelvis (the two hip bones and the middle sacrococcyx) is the bony framework for the lowest part of the trunk (Table 22.1).

Table 22.1: Bones of lower extremity

	Name	Location
Bone attached to trunk forming pelvic girdle	Hip bone	Lowest part of trunk (pelvis)
Bones of free limb	Femur	Thigh
	Tibia	Leg (medially)
	Tarsal bones (7)	Posterior part of foot
	Metatarsal bones (5)	Anterior part of foot
	Phalanges	Toes or digits (3 in each toe and 2 in the big toe)

HIP BONE

Other names: ***Os coxa*** (plural, os coxae; Latin.coxa=hip); ***Innominate bone*** (meaning nameless; so named because of its irregular shape and not conforming to any form).

The hip bone is large and consists of three parts, namely—(1) the ilium, (2) the pubis and (3) the ischium. These three parts meet at the ***acetabulum,*** which is a large deep cavity placed on the lateral aspect of the bone. The acetabulum takes part in forming the hip joint along with the head of the femur. Below and medial to the acetabulum is a large oval or triangular aperture called the ***obturator foramen*** (Figs 22.1 to 22.3).

Ilium: The ***ilium*** (Fig. 22.2) consists of a large plate of bone that lies above and behind the acetabulum, and forms the side wall of the greater pelvis. Its upper border is in the form of a broad ridge that is convex upwards and is called the ***iliac crest***. The posterior part of the ilium bears a large rough articular area on its medial side for articulation with the sacrum.

Pubis: The ***pubis*** (Fig 22.2) lies in relation to the upper and medial part of the obturator foramen. It forms the most anterior part of the hip bone. The two pubic bones meet in the middle line, in front to form the ***pubic symphysis***.

Ischium: The lowest part of the hip bone is formed by the ***ischium*** which lies below and behind the acetabulum and the obturator foramen (Fig. 22.2).

Side Determination

- The acetabular cup or concavity should be facing laterally;
- The ilium should be superior;
- The triangle-shaped pubis with its rami running superior and inferomedial to the obturator foramen should be anterior;

With the aforementioned information, the side of the given hip bone can be determined.

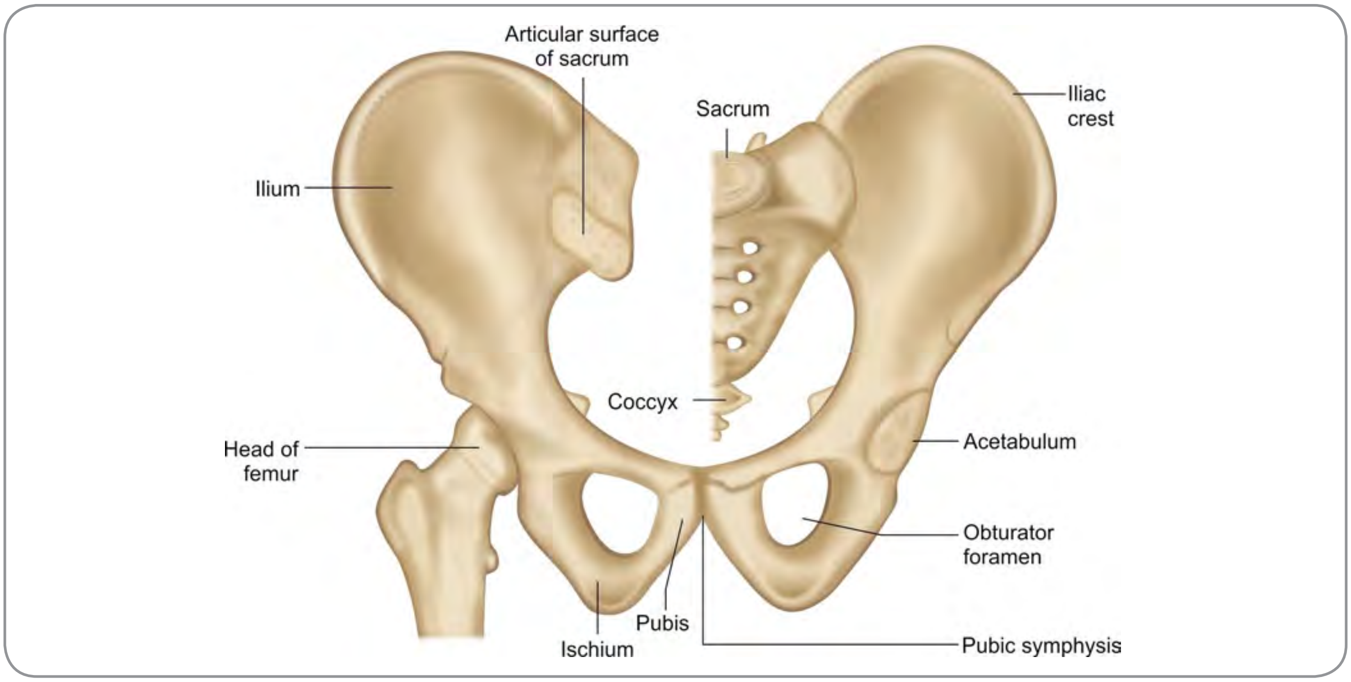


Fig. 22 1: Pelvis viewed from the front; The sacrum is shown only in its left half and the femur only on the right side

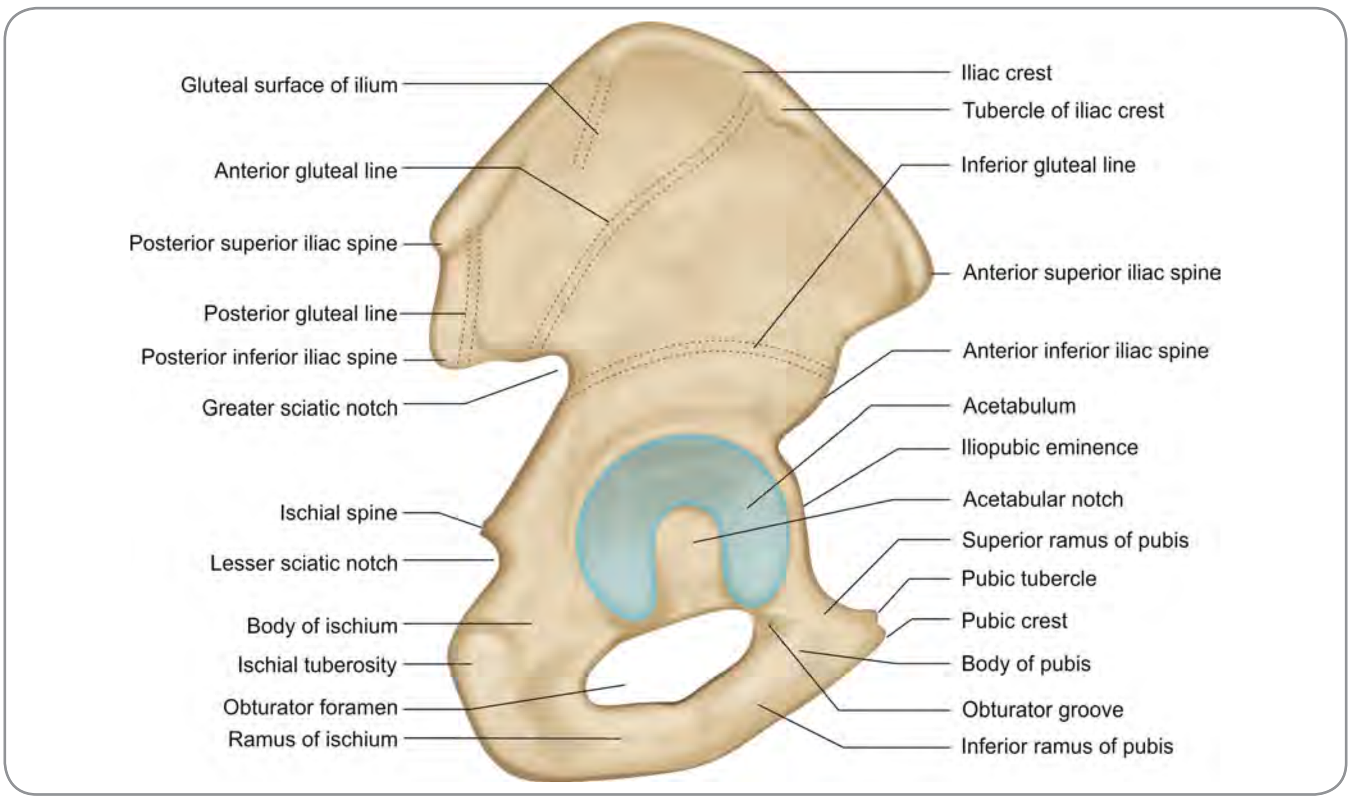


Fig. 22.2: Right hip bone: external aspect

Orientation of the Hip Bone

In the neutral position, anterior superior iliac spines and the top of the pubic symphysis are on the same vertical plane. This position, during study, can be easily obtained by placing the bone against a wall. In this position, the ischial spine is above the superior level of the symphysis and the coccygeal tip is below it. However, in vivo, in the males, the anterior superior iliac spines fall short of the vertical by about half inch. So, the coccygeal tip is

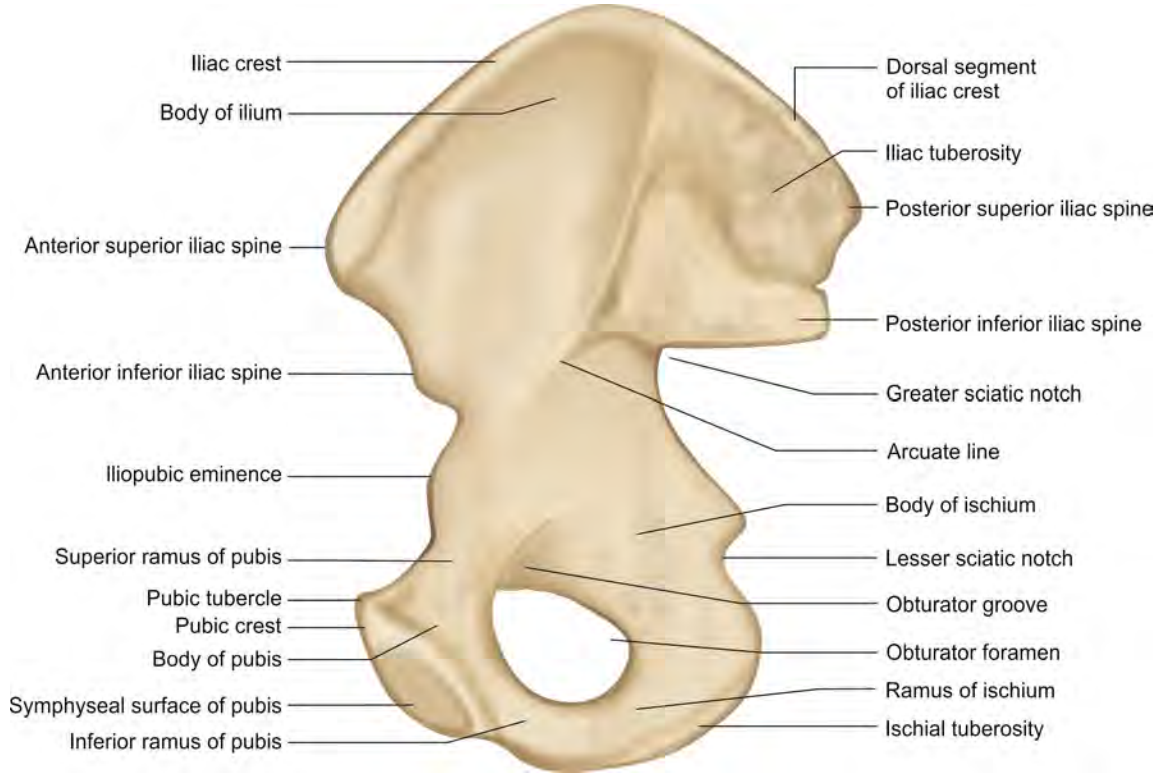


Fig. 22.3: Right hip bone: internal aspect

behind the upper half of the symphysis. In the females, the ASI spines overshoot the vertical by half an inch. So, the coccygeal tip is at level with the superior border of the symphysis. It should be understood that there is a forward tilt of the hip bones (and so the pelvis) in the females and a backward tilt in the males.

Ilium

Other names: Os ilium, flank bone

The ilium (Latin.ilios=flank) is a fan-shaped bone with the narrow part of the fan in the acetabulum The edges of the fan form the anterior and posterior borders; these two are connected superiorly by the curved iliac crest.

Iliac crest: The iliac crest can be felt in the flank region. It has a lateral convexity in its anterior part. The anterior end of the iliac crest projects forwards as the ***anterior superior iliac spine***. The posterior end of the crest also forms a projection called the ***posterior superior iliac spine***. The iliac crest may be subdivided into a ***ventral segment***, consisting of the anterior two-thirds of the crest, and a ***dorsal segment*** consisting of the posterior one-third. The whole length of the ventral segment shows a broad intermediate area that is bounded by inner and outer lips. The outer lip is most prominent and is about 5 cm behind the anterior superior iliac spine. This prominence is called the ***tubercle of the iliac crest***. The inner lip gets obliterated as traced posteriorly. The dorsal segment of the iliac crest has the medial and lateral surfaces separated by a ridge (Fig. 22.3)

Anterior border of ilium: The anterior border of the ilium extends downwards from the anterior superior iliac spine to the acetabulum. Its lowest part presents a prominence called the ***anterior inferior iliac spine***.

Posterior border of ilium: The posterior border of the ilium extends from the posterior superior iliac spine to the back of the acetabulum. A few centimetres below the posterior superior iliac spine the posterior border presents another prominence called the ***posterior inferior iliac spine***. The lower part of the posterior border curves down to form the boundary of a deep notch called the ***greater sciatic notch***. The border joins the posterior border of ischium (Fig. 22.3).

Gluteal surface: The lateral aspect of the ilium constitutes its ***gluteal surface***. This surface is marked by three ridges called the posterior, anterior and inferior gluteal lines. The ***posterior gluteal line*** is vertical. It extends from the iliac crest above, to the posterior inferior iliac spine below. The ***anterior gluteal line*** is convex upwards and backwards. Its anterior end meets the iliac crest in front of the tubercle; while its posterior end reaches the greater sciatic notch. The ***inferior gluteal line*** is horizontal. Its anterior end lies just above the anterior inferior iliac spine; and its posterior end reaches the greater sciatic notch.

The gluteal surface of the ilium bears a prominent groove just above the acetabulum. The lower part of the gluteal surface extends behind the acetabulum where it becomes continuous with the ischium. The lowest part of the ilium forms the upper two-fifths of the acetabulum.

Medial surface: The medial surface of the ilium shows two distinct areas, namely the iliac fossa and the sacropelvic surface. The ***iliac fossa*** is smooth and concave and forms the wall of the greater pelvis. It occupies the anterior part of the medial surface. The ***sacropelvic surface*** lies behind the iliac fossa. It can be subdivided into three parts—(1) the upper part which is rough and which constitutes the ***iliac tuberosity***; (2) the middle part called the auricular surface (because of its resemblance to the shape of pinna), which articulates with the lateral side of the sacrum; (3) the smooth ***pelvic part,*** which lies below and in front of the auricular surface and takes part in forming the wall of the lesser pelvis. A rough groove called the ***preauricular sulcus*** is usually found (especially in females) in this area.

Medial border of ilium: The iliac fossa and the sacropelvic surface are separated by the medial border of the ilium. This border is sharp in its upper part where it separates the iliac fossa from the auricular surface. Its lower part is rounded and forms the ***arcuate line***. The lower end of the arcuate line reaches the junction of the ilium and pubis. This junction shows an enlargement called the ***iliopubic eminence***.

Ischium

Other name: Os ischii

The ischium (Greek.ischion=hip) forms the L-shaped part of the hip bone (Figs 22.1, 22.2 and 22.3) that runs down from the acetabulum and then passes forwards to join the pubis. Thus, the posterior and inferior aspects are made up of ischium.

Body of the ischium: It consists of a main part called the ***body***, the upper part of which forms the inferior and posterior parts of the acetabulum. The ischium also has a projection called the ***ramus surfaces***. The lower part of the body has three surfaces, namely dorsal, femoral and pelvic.

Dorsal surface: The lower part of the dorsal surface has a large rough impression called the ***ischial tuberosity***.

Ischial tuberosity: The ischial tuberosity is divided into the upper and the lower parts by a transverse ridge (Fig. 22.4). Each of these parts is again divided into the medial and the lateral parts. The upper lateral part gives attachment to semimembranous muscle and is separated by an oblique line from the upper medial part which gives attachment to the semitendinosus and biceps femoris. The lower lateral part gives attachment to the hamstrings part of

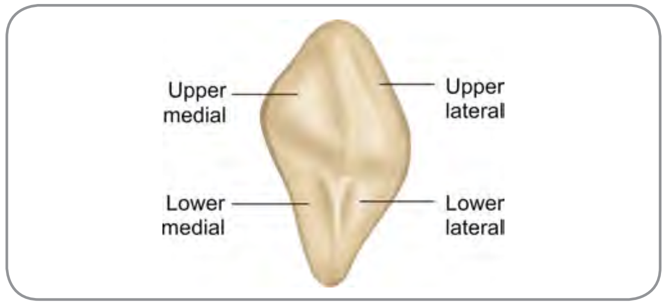


Fig. 22.4: Right ischial tuberosity: seen from behind and below

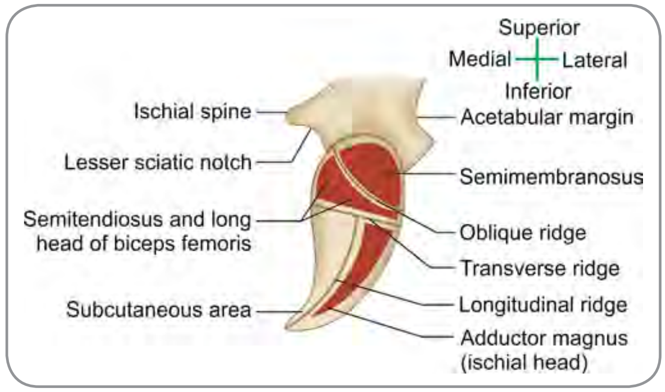


Fig. 22.5: Attachments of ischial tuberosity

the adductor magnus (Fig. 22.5). The lower medial part is covered by fibrous tissue and usually has an overlying bursa due to the pressure produced on sitting. The medial border of the tuberosity provides attachment to the sacrotuberous ligament and the lateral border to the quadratus femoris muscle. The sacrotuberous ligament continues as a sickle-shaped process (the falciform process) along the medial margin of the ischial ramus.

The dorsal surface above the ischial tuberosity has a wide shallow groove. Above this, the dorsal surface becomes continuous with the gluteal surface of the ilium. The posterior border of the dorsal surface of the ischium forms part of the lower margin of the greater sciatic notch Just below this notch, the border projects backwards and medially as the ***ischial spine***. Between the ischial spine and the upper border of the ischial tuberosity is the shallow ***lesser sciatic notch***. The sacrospinous ligament is attached to the ischial spine and along with the sacrotuberous ligament converts the greater and lesser sciatic notches into foramina (Fig. 22.5).

Femoral surface: The femoral surface of the ischium is directed downwards, forwards and laterally. It is continuous with the external surface of the ***ramus of the ischium*** that is attached to the medial side of the lower end of the body.

Pelvic surface: The pelvic surface is smooth and forms the wall of the pelvis. The ramus has an anterior (external)

surface and a posterior (internal) surface. It passes upwards and forwards to join the inferior ramus of pubis; the inferior pubic ramus and the ischial ramus together form the conjoined ischiopubic ramus.

Pubis

Other name: Os pubis

The pubis (Latin.pubez=genital area) forms the anteroinferior part of the hip bone near the midline It consists of a body, a superior ramus and an inferior ramus.

Body of pubis: The ***body*** (Fig. 22.6) forms the anterior and medial parts. It has an anterior surface and a posterior surface. The upper border of the body forms a prominent ridge called the ***pubic crest***. The crest ends laterally in a projection called the ***pubic tubercle***.

Superior ramus: The ***superior ramus*** of the pubis is attached to the upper and lateral parts of the body. It runs upwards, backwards and laterally. Its lateral extremity takes part in forming the pubic part of the acetabulum. It meets the ilium at the iliopubic eminence. The superior ramus is triangular in cross-section (Fig. 22.7) and has three borders and three surfaces. The anterior border is called the ***obturator crest***. The posterior border is sharp and forms the ***pecten pubis*** or ***pectineal line*** (Fig. 22.7). The inferior border is also sharp and forms the upper margin of the obturator foramen. The surface between the obturator crest and the pecten pubis is the ***pectineal surface***. The pelvic surface lies between the pecten pubis and the inferior border. The surface between the obturator crest and the inferior border is called the ***obturator surface*** (Fig. 22.7). A groove runs forwards and downwards across it and is called the ***obturator groove***.

Inferior ramus: The ***inferior ramus*** is attached to the lower and lateral part of the body of the pubis. It passes downwards and laterally to meet the ramus of the ischium. The inferior ramus of pubis and the ramus of ischium

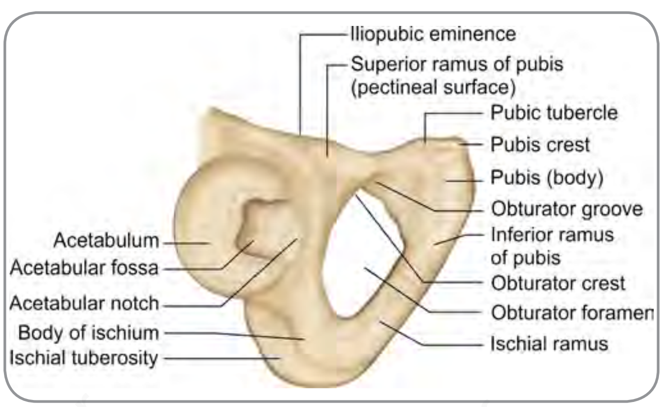


Fig. 22.6: Medial part of right hip bone: anterosuperior aspect

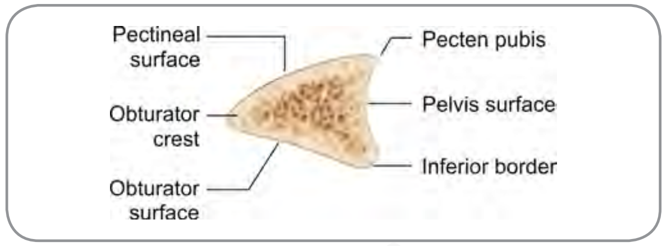


Fig. 22.7: Section at right angles to the long axis of the superior ramus of the pubis

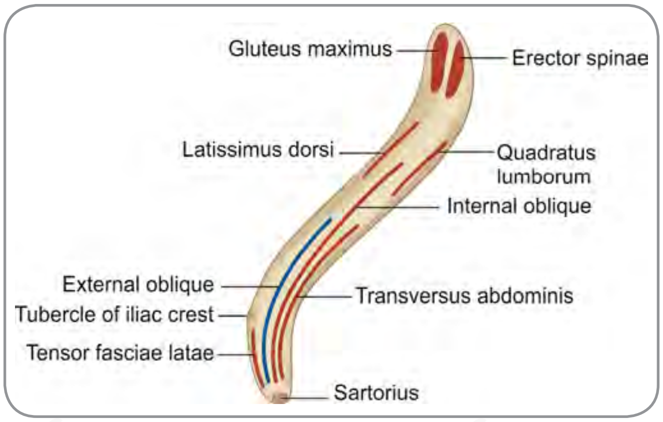
together (called the conjoined ischiopubic ramus) form the medial boundary of the obturator foramen. In the intact pelvis, the conjoined rami of the pubis and isch um of the two sides form the boundaries of the ***pubic arch*** which lies below the pubic symphysis. The inferior ramus of the pubis has an anterior (or outer) surface, and a posterior (or inner) surface. These surfaces are continuous with corresponding surfaces of the ischial ramus.

Acetabulum

The acetabulum is a deep cup-like cavity situated on the lateral aspect of the hipbone. It forms the hip joint with the head of femur. It is directed laterally and somewhat downwards and forwards. The margin of the acetabulum is deficient in the anteroinferior part and the gap in the margin is called the ***acetabular notch***. The floor of the acetabulum is partly articular and partly non-articular. The articular area for the head of femur is shaped like a horseshoe and is called the ***lunate surface*** This surface is widest superiorly. The inner border of the lunate surface forms the margin of the non-articular part of the floor which is called the ***acetabular fossa*** (Fig. 22.6). The upper part of the acetabulum forms a projection on the lower end of ilium for weight transmission to femur.

Obturator Foramen

The obturator foramen can be defined as the triangular space surrounded by the bodies and rami of pubis and ischium. It is bound superiorly by the superior ramus of the pubis; medially by the body of the pubis, inferiorly by its inferior ramus and by the ramus of the ischium; and laterally by the body of the ischium. In the intact body, the foramen is filled by a fibrous sheet called the ***obturator membrane***. However, the membrane is deficient in the uppermost part of the foramen. Where there is deficiency, the membrane has a free upper edge which is separated from the obturator groove of the superior ramus of the pubis by a gap. The two endpoints where the free edge joins the bone usually have the anterior and posterior obturator tubercles.



F g. 22.8: Scheme to show the attachments on the right iliac crest

Attachments of Various Structures

Muscles Attached to the Iliac Crest (Fig. 22.8)

- The ***external oblique muscle of the abdomen*** is inserted into the anterior two-thirds of the outer lip of the ventral segment of the iliac crest.
- The ***internal oblique muscle of the abdomen*** arises from the intermediate area of the ventral segment of the iliac crest.
- The lowest fibres of the ***latissimus dorsi*** take origin from the outer lip of the iliac crest just behind its highest point.
- The ***tensor fasciae latae*** arises from the anterior part of the outer lip of the iliac crest.
- The ***transversus abdominis*** arises from the anterior two-thirds of the inner lip of the ventral segment of the iliac crest.
- The ***quadratus lumborum*** arises from the posterior one-third of the inner lip of the ventral segment of the iliac crest.
- The ***gluteus maximus*** arises from the lateral surface of the dorsal segment of the iliac crest (and from the gluteal surface of the ilium behind the posterior gluteal line).
- The ***erector spinae*** arises from the medial surface of the dorsal segment of the iliac crest.

Muscles Attached to the External Aspect of the Hip Bone (Excluding the Iliac Crest) (Fig. 22.9)

- ***Gluteus maximus*** arises from the gluteal surface of the ilium behind the posterior gluteal line.
- ***Gluteus medius*** arises from the gluteal surface of the ilium between the anterior and posterior gluteal lines.

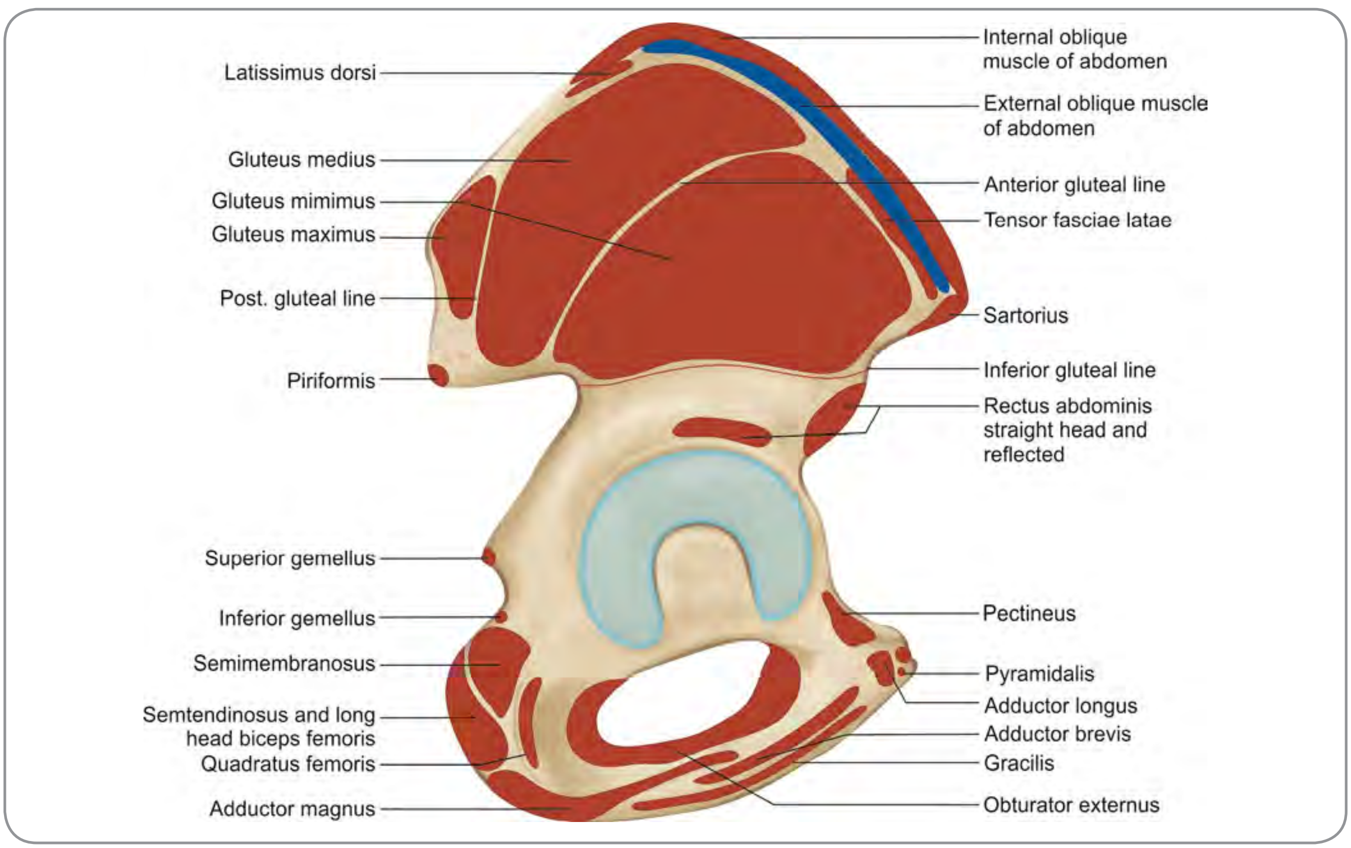


Fig. 22.9: Right hip bone showing attachments: External aspect

- ***Gluteus minimus*** arises from the gluteal surface of the ilium between the anterior and inferior gluteal lines.
- S***artorius*** arises from the anterior superior iliac spine and from a small area below the spine.
- The straight head of the ***rectus femoris*** arises from the anterior inferior iliac spine; and its reflected head from the groove above the acetabulum.
- A few fibres of the ***piriformis*** arise from the upper border of the greater sciatic notch near the posterior inferior iliac spine.
- ***Pectineus*** arises from the upper part of the pectineal surface of the superior ramus of the pubis
- ***Rectus abdominis*** (lateral head) arises from the pubic crest.
- ***Pyramidalis*** and the ***adductor longus*** arise from the anterior surface of the body of the pubis.
- G***racilis*** arises from the anterior surface of the body, and the inferior ramus of the pubis; and from the ramus of the ischium.
- ***Adductor brevis*** arises from the anterior surface of the body of the pubis and its inferior ramus, lateral to the origin of the gracilis.
- ***Obturator externus*** arises from the superior and inferior rami of the pubis, and from the ramus of the ischium, immediately around the obturator foramen.
- ***Adductor magnus*** arises from the lower lateral part of the ischial tuberosity and from the ramus of the ischium.
- ***Semitendinosus*** and the ***biceps femoris*** (long head) arise from the upper medial part of the ischial tuberosity.
- ***Semimembranosus*** arises from the upper lateral part of the ischial tuberosity.
- ***Quadratus femoris*** arises from the femoral surface of the ischium just lateral to the ischial tuberosity.
- ***Superior gemellus*** arises from the dorsal surface of the ischial spine.
- ***Inferior gemellus*** arises from the ischium just above the ischial tuberosity.

Muscles Attached to the Internal Aspect of the Hip Bone (Fig. 22.10)

The ***psoas minor*** is inserted into the pecten pubis and into the iliopectineal eminence.

- ***Iliacus*** arises from the upper two-thirds of the iliac fossa
- ***Obturator internus*** arises from the pelvic surfaces of the superior and inferior rami of the pubis, and the ramus of the ischium, immediately adjoining the obturator foramen and from the pelvic surfaces of the ischium and of the ilium.
- The most posterior fibres of the ***levator ani*** arise from the pelvic surface of the ischial spine and its most anterior fibres from the posterior surface of the body of the pubis.
- ***Coccygeus*** ar ses from the pelvic surface of the ischial spine.

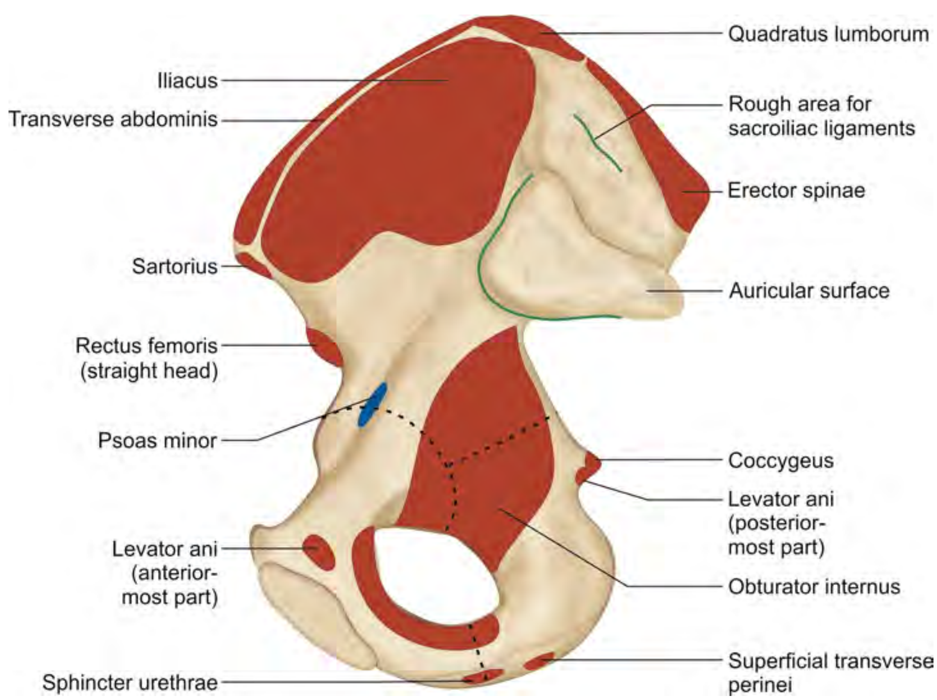


Fig. 22.10: Right hip bone showing attachments: Internal aspect

- ***Superficial transversus perinei*** and the ***Ischio cavernosus*** arise from the posterior surface of the ramus of the ischium.
- S***phincter urethrae*** arises from the posterior surfaces of the inferior pubic and ischial rami.

Attachments of other Structures

- The ***inguinal ligament*** is attached medially to the pubic tubercle and laterally to the anterior superior iliac spine.
- The ***conjoint tendon*** is attached to the pubic crest and to the medial part of the pecten pubis.
- The margin of the acetabulum gives attachment to the ***capsule of the hip joint*** and to the ***acetabular labrum***.
- The ***capsule of the sacroiliac joint*** is attached around the margin of the auricular surface.
- The upper end of the ***sacrotuberous ligament*** is attached to the posterior superior and posterior inferior iliac spines, and to the intervening part of the posterior border of the ilium. The lower end of the ligament is attached to the medial margin of the ischial tuberosity.
- The ***sacrospinous ligament*** is attached to the apex of the ischial spine.

Added Information

- The posterior surface of the pubis is related to the **urinary bladder**.
- The right iliac fossa is related to the **caecum** and **terminal ileum**. The left iliac fossa is related to the terminal part of the **descending colon**.
- The greater and lesser sciatic notches are converted into foramina by the sacrotuberous and sacrospinous ligaments.

Greater and Lesser Sciatic Foramina

The ***greater sciatic foramen*** transmits the following structures:

- Piriformis;
- The superior and inferior gluteal nerves and vessels;
- The internal pudendal vessels;
- The pudendal and sciatic nerves;
- The posterior cutaneous nerve of the thigh;
- The nerves to obturator internus and quadratus femoris.

Having emerged from the greater sciatic foramen, the pudendal nerve, the internal pudendal vessels and the nerve to obturator internus pass behind the ischial spine (posterior to or as seen from the gluteal aspect, over the spine) to enter the ***lesser sciatic foramen***. They pass through the lesser foramen to enter the perineum. The tendon of the obturator internus emerges from the pelvis through the lesser foramen.

Ossification of Hip Bone

The hip bone ossifies before birth from three primary centres, one each for the ilium, the ischium and the pubis. The centres appearing in intrauterine life are as follows—(1) For the ilium – above the greater sciatic notch, in the 8th week; (2) For the ischium – below the acetabulum, in the 4th month; (3) For the pubis – in the superior ramus, in the fourth or fifth month. At birth, the ilium, ischium and pubis are separated by a Y-shaped cartilage present in the region of the acetabulum. The three parts fuse completely only after the age of 18 years.

The inferior ramus of the pubis and the ramus of the ischium are at first separated by cartilage. They fuse with each other at around the seventh year.

Several secondary centres appear-two in the iliac crest, two in the acetabular cartilage, and occasional centres in the anterior inferior iliac spine, the lower part of the acetabulum, the pubic tubercle and the pubic crest.

These centres appear at about the age of puberty or later and fuse with the rest of the bones between 20 and 25 years of age.

Added Information

- The pull of abdominal muscles produces traction epiphyses along the iliac crest.
- The gluteal surface of the ilium is also called the dorsum ilii.
- The ischial tuberosity is also called the tuber ischii.
- The internal surface of the body of the pubis, in vivo, faces directly superiorly, thus forming a floor for the bladder.

PELVIS AS A WHOLE

The bony pelvis, which is the skeleton of the lower abdomen, is made up of the two hip bones, the sacrum and the coccyx (Fig. 22.11). It may be subdivided into the ***greater (or false) pelvis*** and the ***lesser (or true) pelvis***.

The walls of greater pelvis are formed by the broad upper parts of the two iliac bones (iliac fossae) and posteriorly by the base of sacrum. The greater pelvis has no bony ***anterior*** wall and it is merely the lower part of the abdomen.

The communication between the greater and lesser pelvis is called the ***superior pelvic aperture*** or ***pelvic inlet***. The margins of the aperture constitute the ***pelvic brim***. The pelvic brim is formed

- Behind by the sacral promontory, and the ridge separating the superior and anterior surfaces of the sacrum;
- On either side by the arcuate line of the ilium and
- Anteriorly by the pecten pubis and the pubic crest. The arcuate line, the pecten pubis and the pubic crest are collectively referred to as the ***linea terminalis***:

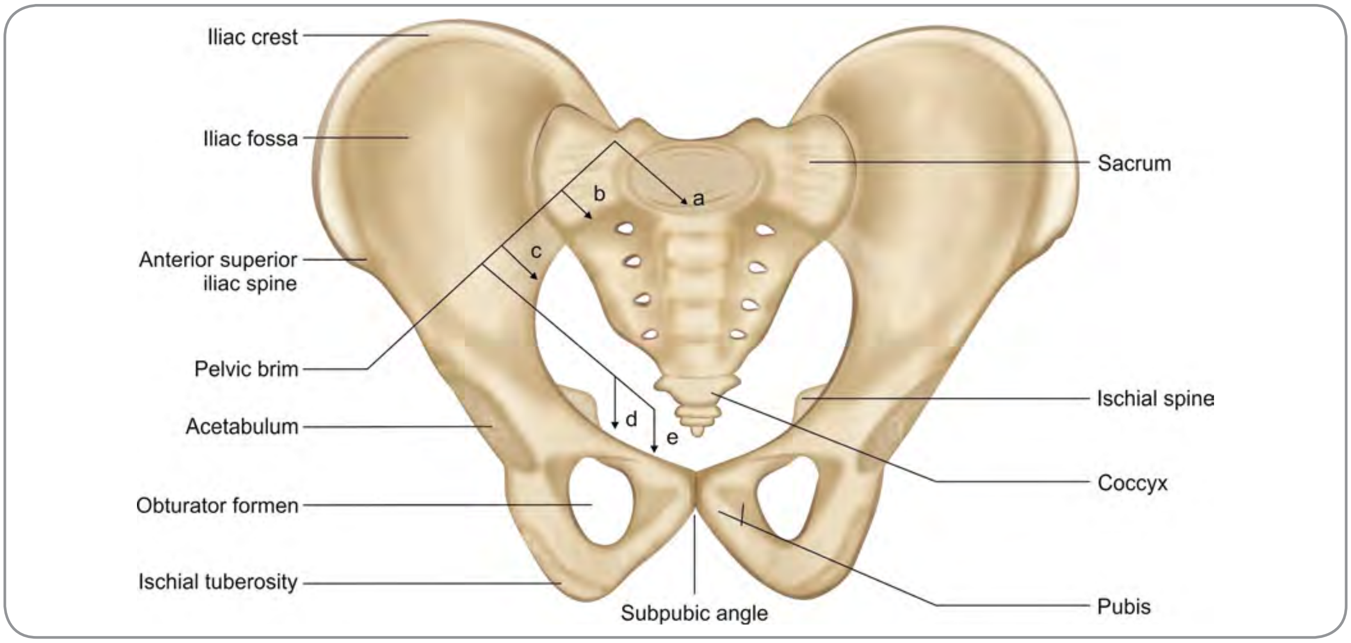


Fig. 22.11: Pelvis seen from the front: a. sacral promontory, b. ala of sacrum, c. iliac arcuate line, d. iliopectineal line, e. pubic crest

The ***cavity of the lesser pelvis*** is bounded:

- In front by the body and rami of the pubis;
- On either side by the pelvic surfaces of the ilium and ischium below the arcuate line and
- Behind by the anterior surfaces of the sacrum and coccyx.

The ***inferior pelvic aperture*** or ***pelvic outlet*** is highly irregular. It is bounded—(1) anteriorly by the pubic arch; (2) laterally by the ischial tuberosity, the lesser sciatic notch, the ischial spine and the greater sciatic notch, in that order; and (3) posteriorly by the lateral margin of the sacrum and coccyx. When the ligaments are intact, the lateral margins are formed by the sacrotuberous ligaments (that stretch from the side of the sacrum and coccyx to the ischial tuberosity) The inferior aperture then appears to be rhomboidal in shape.

Clinical Correlation

Diameters of the Bony Pelvis

The diameters of the pelvic inlet and outlet are important in obstetrics. Some of these are enumerated (all in relation to female pelvis).

Inlet (Fig. 22.12)

- The ***anteroposterior diameter*** is measured from the upper border of the symphysis pubis to the sacral promontory It is about 110 mm;
- The ***transverse diameter*** is measured across the widest part of the pelvic brim. It is about 130 mm;
- The ***oblique diameter*** is measured from one iliopubic eminence to the opposite sacroiliac joint. It is about 125 mm.

contd...

Clinical Correlation *contd...*

Outlet (Fig. 22.13)

- The ***anteroposterior diameter*** is measured from the apex of the coccyx to the lower border of the symphysis pubis. It is about 125 mm;
- The ***transverse diameter*** is measured between the two ischial tuberosities. It is about 110 mm;
- The ***oblique diameter*** is measured from the midpoint of the sacrotuberous ligament of one side to the junction of the ischial and pubic rami on the other side. It is about 118 mm.

Sex Differences in the Pelvis

Of all the bones of the human skeleton, sexual differences are most marked in the pelvis, and these are useful in deciding whether a given pelvis belongs to a male or a female individual. As a rule, the male pelvis is more strongly built than in a female, and the bones have more prominent muscular markings. All

contd...

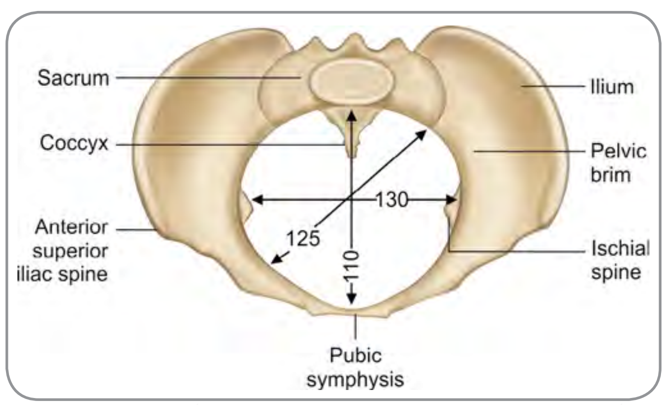


Fig. 22.12: Anteroposterior view of the pelvis to show the diameters of the pelvic inlet (in mm)

Clinical Correlation *contd...*

the articular areas including the acetabulum are larger in male, for transmission of greater body weight. In contrast, the female pelvis is adapted for the function of child-bearing. For this purpose, the true pelvis is broader and shallower than in a male.

Some features useful in deciding the sex of a given pelvis are listed below. However, all features have to be taken together, no one feature being decisive.

- The ***subpubic angle*** (i.e., the angle between the right and left ischiopubic ami) is almost ninety degrees in female, but is only fifty to sixty degrees in male. The angle is sharp in male, but tends to be rounded in female (a in Fig. 22.14A and B).
- The medial edges of the ***ischiopubic rami*** (b in Fig. 22.14A and B) may be markedly everted in a male for attachment of the crura of the penis.
- In a male, the distance from the pubic symphysis to the anterior margin of the acetabulum is equal to the total width of the acetabulum, but in a female, the distance from the pubic symphysis to the anterior margin of the acetabulum is distinctly more than the width of the acetabulum.
- In female ***sacrum***, the width of the articular area for the body of the fifth lumbar vertebra is equal to the width of the lateral part (or ala) (Fig. 22.15). On the other hand, in a male, the width of the body is distinctly more than the width of the lateral part.
- The ***pelvic inlet*** is rounded in a female, but tends to be heart-shaped in a male. The male inlet is smaller in all diameters (Fig. 22.16).
- The ***preauricular sulcus*** is deeper and more prominent in a female.

Fractures of Pelvis

- These are not common. These may occur through the superior or inferior ischiopubic ramus, near the junction of the pubis and ischium (when they may involve the acetabulum) or the lateral part of the ilium. Isolated fractures of one part of the

contd ..

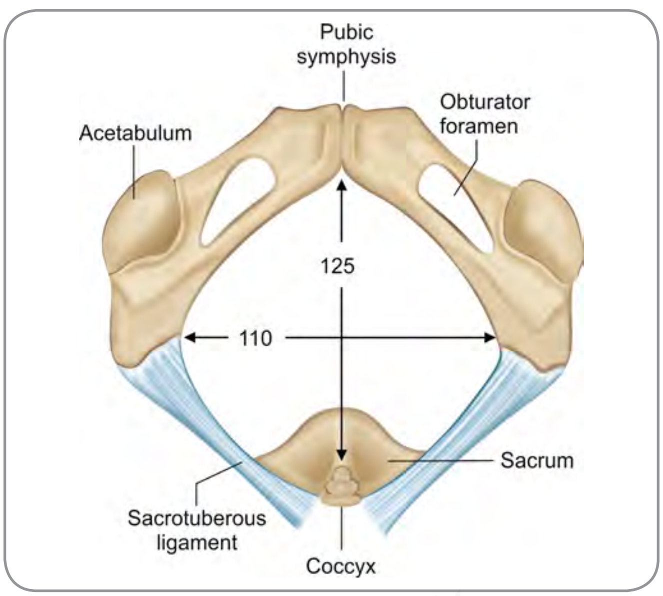


Fig. 22.13: Pelvic outlet seen from below

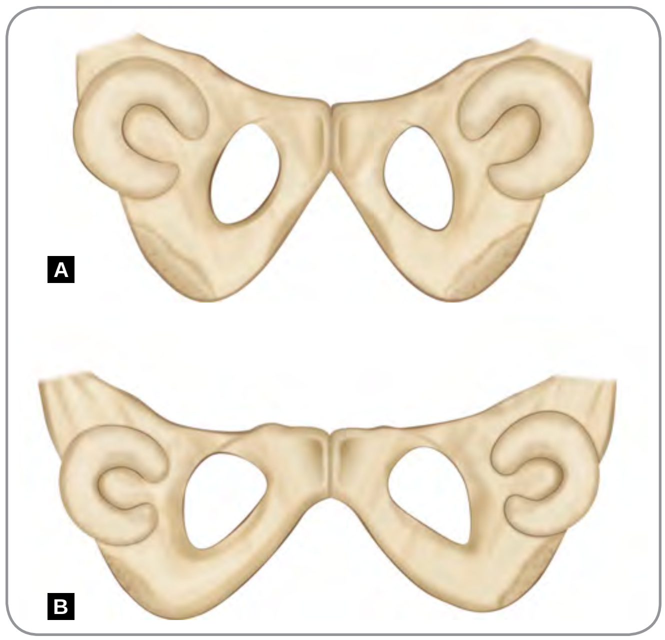
Clinical Correlation *contd...*

pelvis are usually not serious as long as the ring formed by the two hip bones and sacrum is not disrupted.

- Dis uption of the ring occurs when it is broken (or dislocated) at two points (e.g., fracture of both ischiopubic rami combined with dislocation at the sacroiliac joint). When disruption occurs, there can be injury to the urinary bladder, the urethra, the rectum or the vagina. Injury to a large artery in the pelvic wall can cause severe bleeding. In serious disruption of the pelvis, there may be permanent damage to nerves of the lumbosacral plexus.
- When a fracture of the pelvis involves the acetabulum, it can eventually lead to osteoarthritis of the hip joint.
- Extremely strong contraction of muscles (in competitive sports) can tear off a tendon from its attachment along with a small piece of bone. The anterior superior and anterior inferior i iac spines can be torn off. These are called ***avulsion fractures***.

Others

In older women, the upper parts of the iliac fossae are thin and translucent due to osteoporosis.



Figs 22.14A and B: Anteroinferior aspect of the pelvis **A.** n the male and **B.** in the female

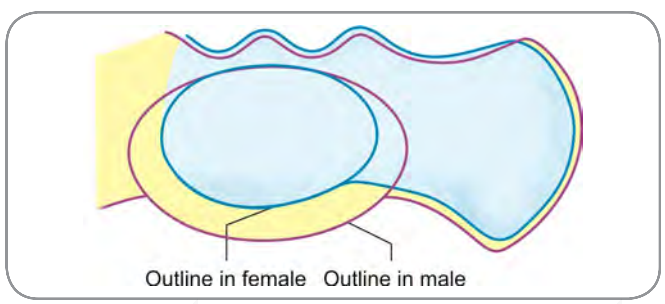


Fig. 22.15: Compa ison of the relative sizes of the articular surface on the sacrum for the body of the fifth lumbar vertebra in the male and female

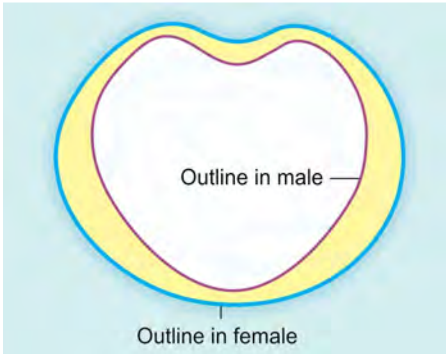


Fig 22.16: Shape and relative sizes of the pelvic inlet in the male and female

FEMUR

The femur (Figs 22.17 to 22.23) (Latin.femure=thigh) or the thigh bone is the longest and the strongest bone of the body. At its upper end, it articulates with the acetabulum of the hip bone and at its lower end, it articulates with the tibia and the patella. Thus, the femur extends from the hip to the knee. It is a long bone with a shaft, an upper end and a lower end.

Side Determination

The upper end is easily distinguished from the lower end by the presence of a rounded head that is joined to the shaft by an elongated neck.

The head is directed medially to articulate with the acetabulum of the hip bone

The anterior and posterior aspects of the bone can be distinguished by examining the shaft as it convexes forwards and the anterior aspect is smooth, while the posterior aspect is marked by a prominent vertical ridge called the ***linea aspera***.

With the above information, superior-inferior, medial-lateral, and anterior-posterior aspects of the bone can be distinguished and, therefore, the side determined.

Orientation of the Bone

The condyles of the bone rest on the tibia as they would rest on a horizontal surface. The head and neck, as they are directed upwards, forwards and medially, are a little in front of the shaft. The shaft itself is not vertically straight but is inclined forwards in the upper part.

Upper End (Figs 22.17 to 22.20)

The upper end consists of the head and the neck, and two other projections called the ***greater*** and ***lesser trochanters*** (Latin.trocantere=a rummer).

Head: The ***head***, apart from being directed medially, is also directed upwards and somewhat forwards. It is much

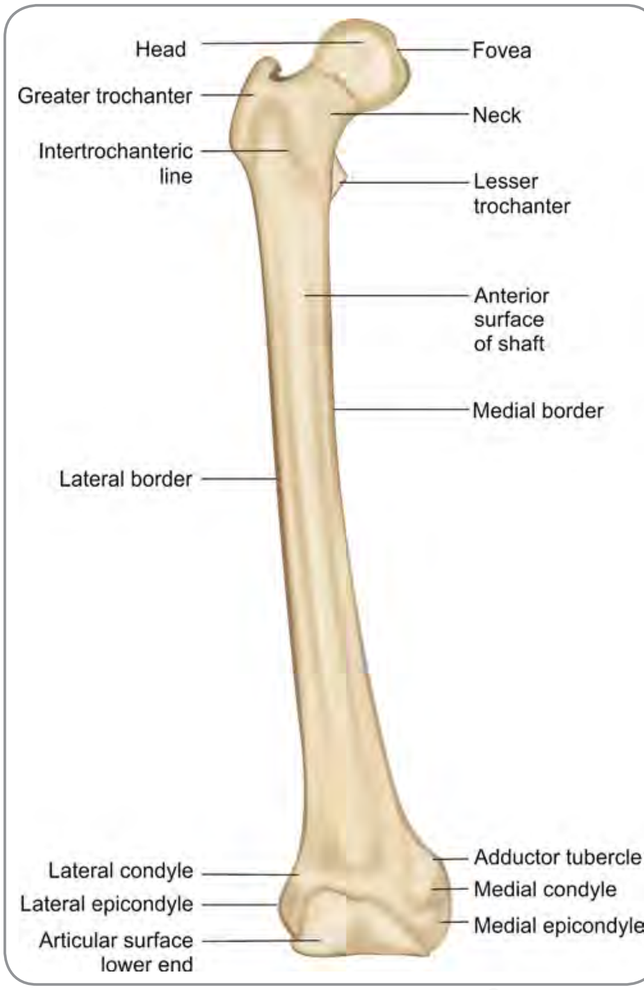


Fig. 22.17: Right femur: anterior aspect

more rounded than the head of the humerus and is slightly more than half a sphere. It articulates with the acetabulum of the hip bone and is covered with articular cartilage. Near its centre (and a little posteromedially) is a pit or ***fovea*** (***fovea capitis femoris***).

Neck: The ***neck*** connects the head to the shaft. It joins the shaft at an angle of about 125 degrees (Fig. 22.19). This angle, which varies with age and build of the individual, is smaller in adults, in women and in short people The size of the angle is also associated with the width of the pelvis. The anterior surface of the neck presents many grooves and numerous foramina for blood vessels. The posterior surface is smooth. Though the neck is functionally and developmentally a part of the shaft, it is separated from the shaft by the intertrochanteric line in front and the intertrochanteric crest behind

The greater and lesser trochanters are situated near the junction of the neck with the shaft.

Greater trochanter: The ***greater trochanter (trochanteris major)*** (Fig. 22 19) forms a large quadrangular projection on the lateral aspect of the upper end. Its upper and posterior part projects upwards beyond the level of the neck

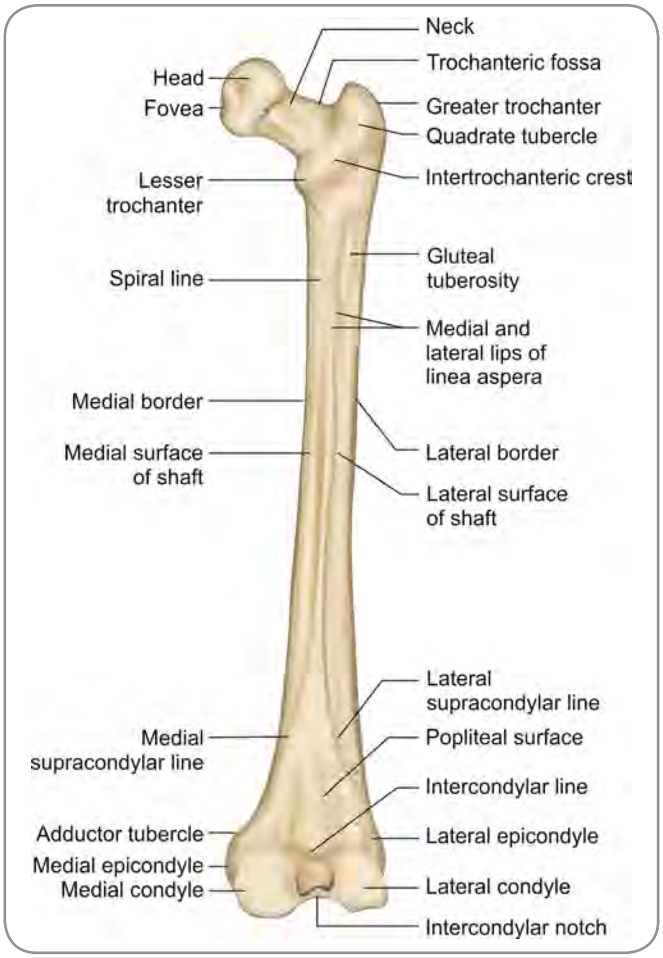


Fig. 22.18: Right fem r: posterior aspect

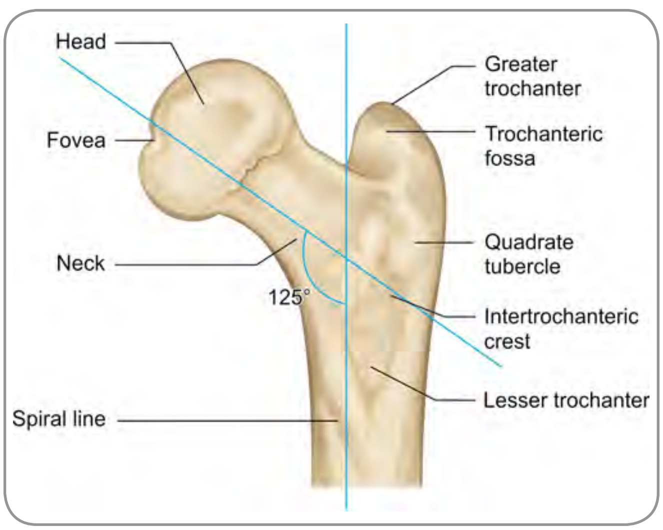


Fig. 22.19: Right femur: posteromedial view of upper end

and thus comes to have a medial surface. On this medial surface, is a small depression called the ***trochanteric fossa***. The greater trochanter also has an anterior, a lateral and a posterior surface. The anterior surface shows a large rough area for muscular attachments.The lateral surface is also marked by an area for muscular attachments; the area

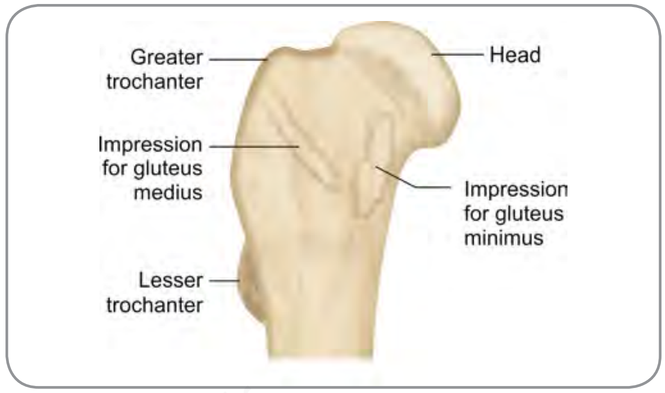


Fig. 22.20: Right femur: lateral aspect of upper end

is in the form of a ridge or a flat strip that runs downwards and forwards across the lateral surface. The upper part which projects upwards is on the same level as the centre of the hip joint and the upper border of symphysis pubis. The projecting conical point of the upper part is called the ***tip of the trochanter***.

Lesser trochanter: The ***lesser trochanter*** (***trochanteris minor*** or the ***small trochanter***) is a conical projection attached to the shaft where the lower border of the neck meets the shaft. It points medially and backwards.

Intertrochanteric crest: The posterior parts of the greater and lesser trochanters are joined together by a prominen ridge called the ***intertrochanteric crest*** (Fig. 22.19).

Quadrate tubercle: A little above its middle this crest bears a rounded elevation called the ***quadrate tubercle***.

Intertrochanteric line: Anteriorly, the junction of the neck and the shaft is marked by a much less prominent ***intertrochanteric line***. The upper end of this line reaches the anterior and upper part of the greater trochanter and its lower end lies a little in front of the lesser trochanter. Just below the lesser trochanter, the intertrochanteric line becomes continuous with the ***spiral line*** that runs downwards and backwards across the medial aspect of the shaft to reach its posterior aspect.

Shaft

The shaft (otherwise called the body) of the femur has a forward convexity and widens above and below to join with the respective ends. It is smooth anteriorly but its posterior aspect is marked by a rough vertical ridge called the ***linea aspera*** (Fig. 22.17).

The shaft is triangular having three borders (lateral, medial and posterior) and three surfaces (anterior, lateral and medial) (Fig. 22.21) The lateral and medial borders are rounded. The posterior border corresponds to the linea aspera.

The anterior surface is very smooth. The medial and lateral surfaces are actually posteromedial and posterolateral because both of them face backwards too.

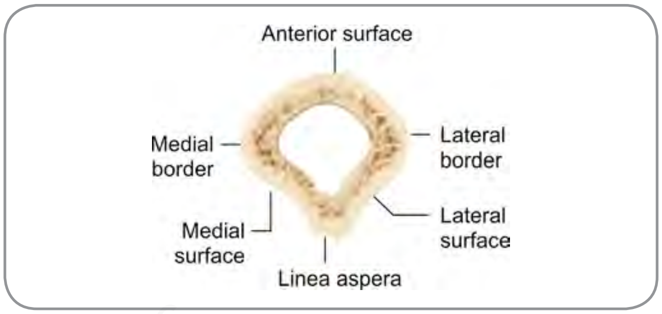


Fig. 22.21: Transverse section across the shaft of the femur near its middle

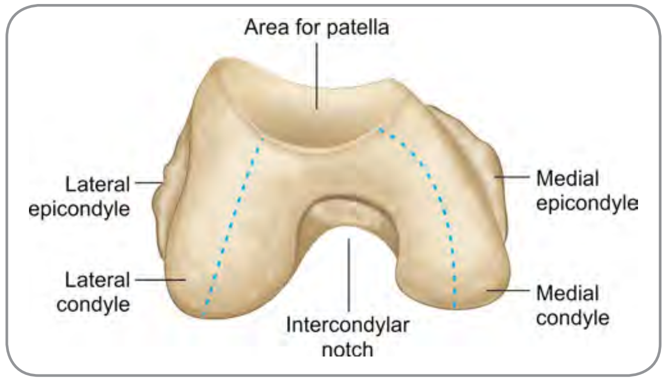


Fig. 22.22: Right femur: end lower viewed from below

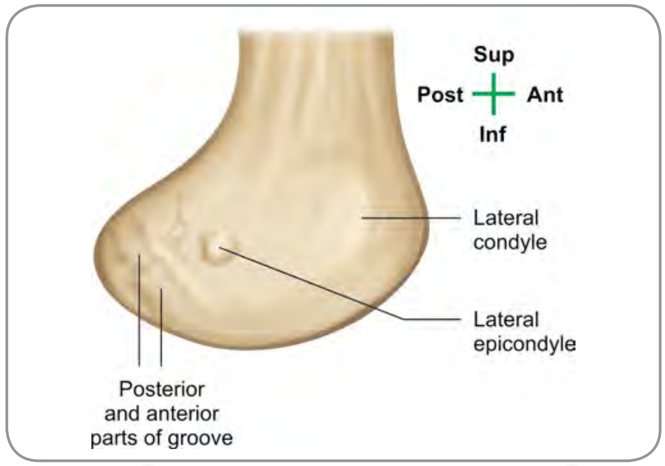


Fig. 22 23: Right femur: lower end seen from the lateral side

The linea aspera has distinct medial and lateral lips. When traced upwards to the upper one-third of the shaft, the lips diverge. The medial lip becomes continuous with the spiral line. The lateral lip becomes continuous with a broad rough area called the ***gluteal tuberosity***. The upper end of the gluteal tuberosity reaches the greater trochanter. The area between the gluteal tuberosity (laterally) and the spiral line (medially) constitutes a fourth surface (posterior) over the upper one-third of the shaft. The two lips of the linea aspera diverge from each other over the lower one third of the shaft to become continuous with ridges called the ***medial and lateral supracondylar lines***. There again, the shaft has an additional surface directed posteriorly. This surface is triangular and is called the ***popliteal surface***.

Lower End

The lower end of the femur consists of the two large condyles (Greek.kondylus=knuckle, any rounded prominence) called the medial and lateral condyles. Anteriorly, the two condyles are joined together and lie in the same plane as the lower part of the shaft (Fig. 22.22). Posteriorly, they project much beyond the plane of the shaft, and are separated by a deep ***intercondylar notch*** or fossa (Fig. 22.22). When the femur is in normal position, the distal surfaces of the two condyles should lie on the same horizontal plane; thereby the shaft is directed upwards and outwards from the knee to the hip.

When viewed from the side (Fig. 22.23), the lower margin of each condyle is seen to form an arch that is convex downwards. When seen from below, the long axis (herein, the anteroposterior axis) of the lateral condyle is straight and is directed backwards and a little laterally In contrast, the medial condyle is slightly curved with a medial convexity, making its long axis also curved.

The anterior aspect of the two condyles is marked by an articular area for the patella. The area is concave from side to side to accommodate the convex posterior surface of the patella. It is divided into the medial and lateral parts. The lateral part is larger. Inferiorly, the condyles articulate with the tibia to form the knee joint For this purpose, each condyle (separately) bears a large convex articular surface that is continuous anteriorly with the patellar surface. The tibial articular surface covers the inferior and posterior aspects of each condyle.

When viewed from the lateral aspect, the lateral condyle of the femur is seen to be more or less flat. A little behind the middle, it is marked by a prominence called the ***lateral epicondyle*** (Greek epi=above or over; over the condyle) Behind and below the epicondyle is a prominent groove that is divided in o an anterior deeper part and a shallower posterior part This is the groove for popliteus muscle.

When viewed from the medial aspect, the medial condyle is seen to be convex. The most prominent point on it is the ***medial epicondyle*** (Fig. 22.22). The uppermost part of the medial condyle is marked by a sharp prominence called the ***adductor tubercle*** (Fig. 22.18) This tubercle lies above and behind the medial epicondyle and is continuous with the lower end of the medial supracondylar line.

Posteriorly, between the condyles is a rough area with several vascular foramina. This area is limited above by the intercondylar line and below by the articular edge The hollow portion on the posterior aspect between the two condyles is often referred to as the condylar or intercondylar fossa.

Attachments of Various Structures

Muscular Insertions (Figs 22.24 and 22.25)

Several important muscles gain insertion into the femur. For easy understanding and convenience, we shall consider them in relation to the prominent parts of the bone.

Greater Trochanter

- The ***gluteus minimus*** is inserted into the anterior aspect of the greater trochanter.
- The ***gluteus medius*** is inserted into the oblique strip running downwards and forwards across the lateral surface of the greater trochanter.
- The ***piriformis*** is inserted into the upper border of the greater trochanter.
- The ***obturator internus*** and ***gemelli*** are inserted into the anterior part of the medial surface of the greater trochanter.
- The ***obturator externus*** is inserted into the trochanteric fossa on the medial surface of the greater trochanter.

Lesser Trochanter and Around

- The ***psoas major*** is inserted into the medial part of the anterior surface of the lesser trochanter.
- The ***iliacus*** is inserted into the medial side of the base of the lesser trochanter, and into a small area below the latter.
- The ***pectineus*** is inserted along a line descending from the root of the lesser trochanter to the upper end of the lineaaspera. The insertion lies between the gluteal tuberosity and the spiral line.

Other Areas

- The ***quadratus femoris*** is inserted into the quadrate tubercle (intertrochanteric crest), and into a small area below the latter.
- The deep fibres of the ***gluteus maximus*** are inserted into the gluteal tuberosity.
- The upper part of the ***adductor brevis*** is inserted between the insertions of the pectineus (medially) and the adductor magnus (laterally). The lower part of the muscle is inserted into the linea aspera.

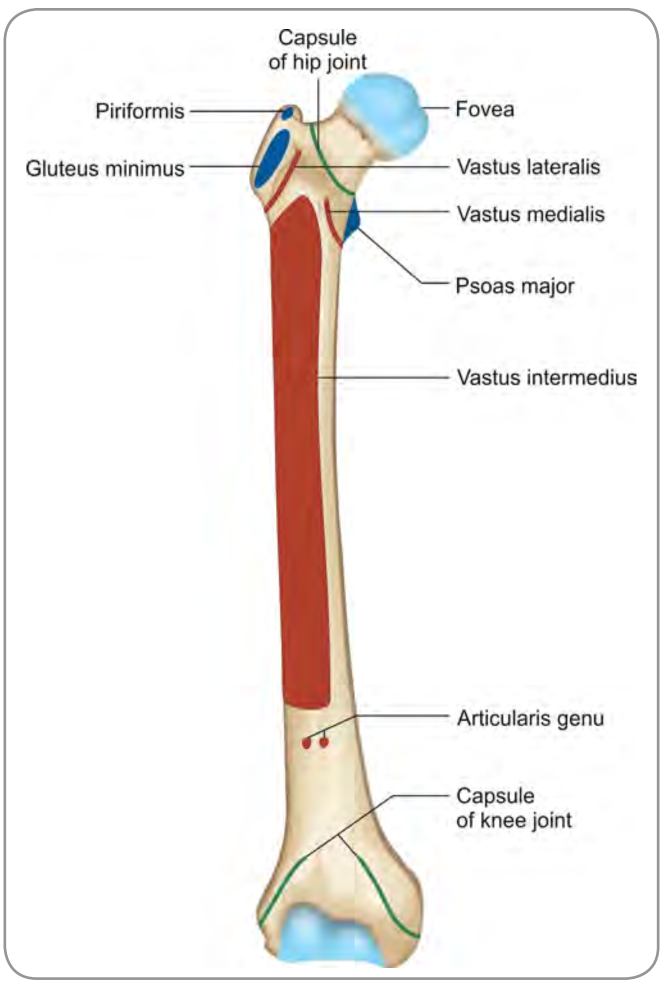


Fig. 22.24: Right femur: showing attachments seen from the front

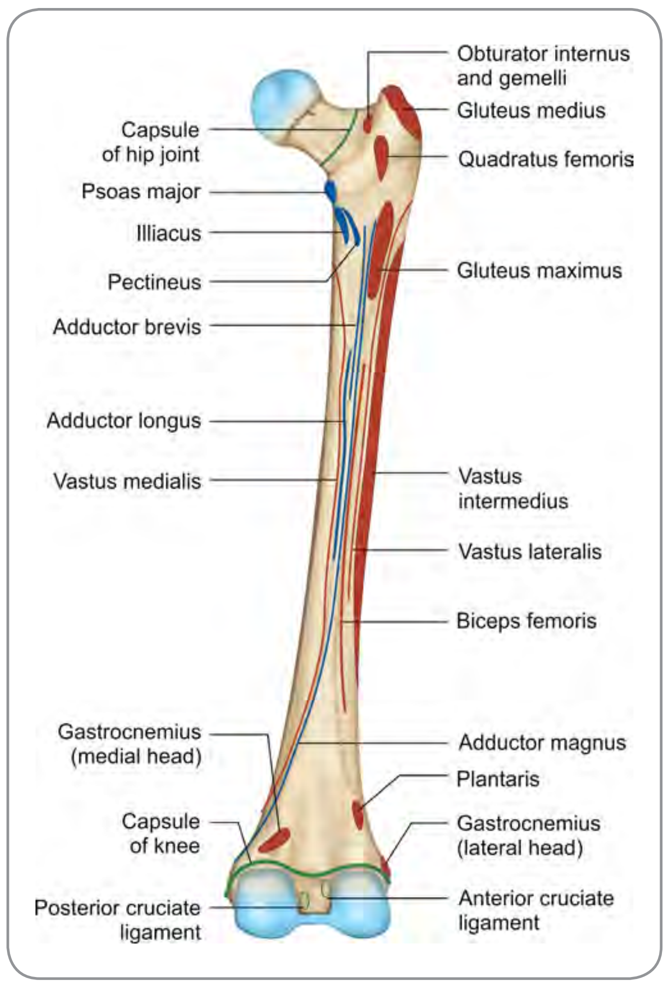


Fig. 22.25: Right femur: showing attachments seen from behind

- The ***adductor longus*** is inserted into the middle one-third of the linea aspera.
- The ***adductor magnus*** is inserted into the medial margin of the gluteal tuberosity, the linea aspera, and the medial supracondylar line. The hamstring part of the muscle ends in a tendon that is attached to the adductor tubercle.

Muscular Origins (Fig. 22.24)

Large and strong muscles of the thigh take origin from the thigh bone.

- The ***vastus lateralis*** has a long linear origin. The line begins at the upper end of the intertrochanteric line. It passes along the anterior and lower borders of the greater trochanter, the lateral margin of the gluteal tuberosity and the lateral lip of linea aspera.
- The ***vastus medialis*** also has a long linear origin from the lower part of the intertrochanteric line, the spiral line, the medial lip of the linea aspera and the medial supracondylar line right up to the adductor tubercle.
- The ***vastus intermedius*** arises from the upper three-fourths of the anterior and lateral surfaces of the shaft. The medial surface of the shaft does not give origin to the muscle, but is covered by it.
- The ***articularis genu*** arises from small areas on the anterior surface of the shaft below the origin of the vastus intermedius.
- The short head of the ***biceps femoris*** arises from the linea aspera and from the upper part of the lateral supracondylar line.
- The medial head of the ***gastrocnemius*** arises from the popliteal surface a little above the medial condyle. The lateral head of the muscle arises from the lateral surface of the lateral condyle.
- The ***plantaris*** arises from the lower part of the lateral supracondylar line.
- The ***popliteus*** arises (by a tendon) from the anterior part of the groove on the lateral aspect of the lateral condyle.

Attachments of Fascial and Fibrous Structures

- The medial and the lateral intermuscular septa, which are derived from the fascia lata are attached to the medial and lateral lips of the linea aspera. The posterior intermuscular septum, also a derivative of fascia lata is attached to the intermediary space between the two lips
- The ***capsule of the hip joint*** is attached to the neck of the femur. Anteriorly, the capsule is attached to the intertrochanteric line. But posteriorly it is attached about 1cm medial to the intertrochanteric crest. Because of this attachment, most of the neck lies within the hip joint capsule; the anterior part of neck is completely in racapsular but the posterior part is partly so.
- The ***ligament of the head (ligamentum teres)*** is attached to the fovea on the head of the femur.
- The ***capsule of the knee joint*** is attached to the femoral condyles and to the posterior margin of the intercondylar fossa:
  - On the lateral condyle, it is attached above the origin of the popliteus.
  - The capsule is deficient anteriorly, where it is replaced by the patella.
- The ***anterior cruciate ligament*** is attached to the medial surface of the lateral condyle.
- The ***posterior cruciate ligament*** is attached to the lateral surface of the medial condyle.

Added Information

- The tip of the greater trochanter can be palpated about a hand's breadth below the midpoint of iliac crest.
- The forward convexity of femoral shaft jeopardises the straight line of weight transmission. However, this is compensated by the thick ridge of linea aspera.
- The gluteal tuberosity may be very prominent; if it projects high, it is called the third trochanter.
- The intracondylar notch of the lower end is intracapsular.

Ossification

The femur is the second long bone in the body to start ossifying (the first being the clavicle).

The ***primary centre*** appears in the shaft during the 7th foetal week. It may be noted that the neck of the femur ossifies from the primary centre.

Three ***secondary centres*** appear at the upper end of the bone; one each for the head (first year), the greater trochanter (fourth year), and the lesser trochanter (around the twelfth year). Each of these centres fuses independently with the shaft in the reverse order of appearance—(1) the lesser trochanter at about 13 years, (2) the greater trochanter at about 14 years and (3) the head around 16 years.

One secondary centre for the distal end appears before birth in the 9th month of foetal life. It fuses with the shaft between the 16th and 18th (or 19th) year.

Clinical Correlation

- The appearance of the lower end epiphysis of the femur before birth has a medicolegal significance. It can be used as a proof of viability in cases of newborn deaths.
- The lower end of the bone is the growing end. The nutrient foramen is directed upwards.
- The lower epiphyseal line passes through the adductor tubercle. Injury to the epiphysis before fusion will shorten the limb.

contd...

Clinical Correlation *contd...*

- The angle between the neck and shaft of the femur may be less than normal (***coxa vara***) or more than normal (***coxa valga***).
- ***Absence*** of the proximal part of the femur is a very rare congenital anomaly.
- The hip joint is a common site of ***congenital dislocation*** occurring as a result of imperfectly formed bone ends. Rarely, the knee may be similarly affected.
- The femur may be fractured through the neck, through the trochanteric region, through the shaft (at any level), just above the condyles (supracondylar fracture) or through one of the condyles.
- **Fracture of the Neck of the Femur:** This fracture is common in old persons (especially, post-menopausal women) in whom the region has been weakened by osteoporosis. It can occur as a result of slight injury which is usually a rotational force. The fractured limb shows marked lateral rotation. The fracture can be intracapsular or extracapsular. Intracapsular fractures are complicated because of two reasons—(1) The binding of the joint capsule is lost; the two break-away parts are pulled and rotated discordantly due to muscular action; (2) Blood supply to the head of femur is compromised. Blood supply to the head is derived from three sources namely nutrient vessels passing through the neck to reach the head, vessels entering the upper end of the femur along the attachment of capsule of the hip joint, and vessels entering the head through the ligamentum teres. Following fracture of the neck of the femur, the first two are injured and the only remaining supply s that through the ligamentum teres. Lack of adequate blood supply can be responsible for delayed union, or non-union of the fracture.
- Insufficient blood supply to the head leads to ***avascular necrosis*** of the head. The head collapses and the hip joint becomes disorganised, leaving the patient with a permanent limp.
- The joint can be repaired using artificial (metallic) components. This is called ***arthroplasty***.
- Fractures through the shaft of the femur are caused by severe injuries (like car accidents). Such injuries may also cause a simultaneous dislocation of the hip joint. The femoral artery or the sciatic nerve can be injured by the sharp edge of the fractured shaft.
- A fracture through the femoral condyles may involve the knee joint. The popliteal artery or a nerve in the region may be injured.

Added Information

- On an average, the length of femur is about a quarter of the individual's length.
- In a child, the pelvis is narrow and so the neck and shaft of femur are almost in line with each other. As the pelvis widens, the neck becomes more horizontal, leading to a neck-shaft angle of about 125 degrees.
- The greater trochanter is the traction epiphysis of Gluteus med us and Gluteus minimus.
- The lesser trochanter is the traction epiphysis of the iliopsoas.
- The epiphyseal line of the lower end of femur runs through the adductor tubercle and along the intercondylar line.

contd...

Added Information *contd...*

- Platymeria, a condition where the upper part of the shaft of femur is markedly flattened anteroposteriorly, occurs in primitive races.
- The femora are directed obliquely so that while standing, the knees are adjacent to each other and the line of centre of gravity falls within the legs and feet. This is essential for bipedal gait and also for maintaining balance in erect position which the human race has acquired.
- The neck-shaft angle is the angle of inclination.
- The long axis of the head and neck and the transverse axis of the lower end are at an angle to each other. This is the angle of femoral torsion or the angle of declination. It is about 7 degrees in males and 15 degrees in females. The angle of torsion and the angle of inclination together facilitate the various movements of the femoral head within the obliquely placed acetabulum.

PATELLA

Other name: knee cap

The patella (Latin.patina= a plate) is a sesamoid bone in the tendon of quadriceps femoris muscle. It is the largest sesamoid bone in the body.

Side Determination

The patella is shaped somewhat like a disc (Fig. 22.26 and 22.27) with a process (called the apex) that projects inferiorly.

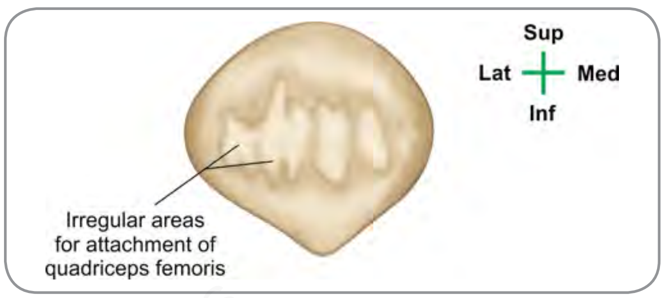


Fig. 22 26: Right patella: anterior aspect

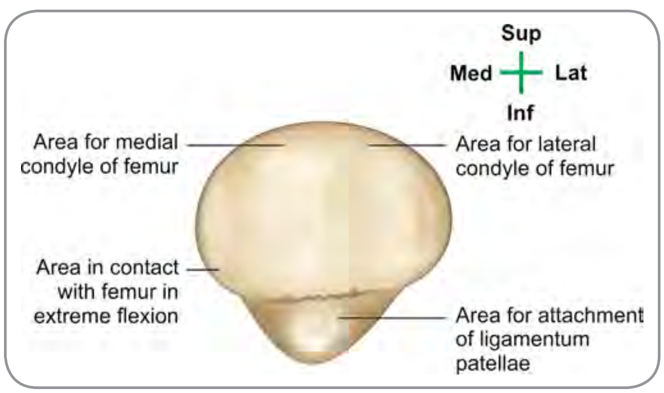


Fig. 22.27: Right patella: posterior aspect

The anterior surface is rough with several vertical striations.

The posterior surface has a large articular facet which is subdivided into large lateral and small medial areas.

With these features, the side of the given patella can be determined.

Features

The bone is roughly triangular in outline. It has anterior and posterior surfaces that are separated by three borders, namely—superior, medial and lateral. The superior border is also called the ***base***. The medial and lateral borders are the medial and lateral margins of the bone; they are rounded. The inferior part of the bone shows the downward projection called the ***apex*** (Fig. 22.26).

The ***anterior surface*** is rough and can be felt through the overlying skin. It is slightly convex and is vertically striated by the fibres which run over it. Most of the ***posterior surface*** is articular. It articulates with the patellar surface on the anterior aspect of the condyles of the femur. It consists of a larger lateral part and a smaller medial part, the two parts being separated by a ridge. The lateral and medial parts are further subdivided by faint ridges into superior, middle and inferior facets. The inferior facets are in contact with the patellar surface of femur in complete extension, the middle facets in partial extension and the superior facets in flexion. The most medial part of the articular area may be recognisable as a separate area. This part articulates with the medial condyle of the femur only in extreme flexion of the knee joint. The lower part of the posterior surface is non-articular. It is rough for attachment of the ligamentum patellae.

Attachments on the Patella

- The superior border gives attachment to the quadriceps ***femoris*** (the rectus and the three vasti). Some of these fibres continue over the anterior surface to join the ligamentum patellae (Fig. 22.28).
- The apex and the adjacent part of posterior surface give attachment to the ***ligamentum patellae***.
- The medial and lateral borders receive fibres of vastus medialis and lateralis respectively and also fibres of fascia lata. The collected fibres of the concerned muscle and the fascia lata together form the medial and the lateral patellar retinaculum respectively.

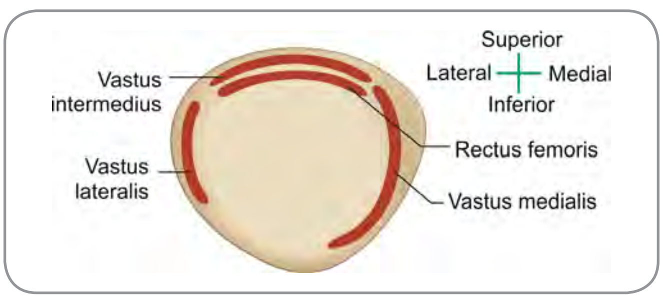


Fig. 22.28: Attachments of patella

Ossification

The patella ossifies from several centres that appear between the third and sixth years of life. The centres soon fuse with one another.

TIBIA

Other names: shin bone, shank bone

The tibia (Latin.tibia=shin bone) is the medial bone of the leg. It extends from the knee to the ankle and is felt along its whole length on the anteromedial aspect of the leg. It has a shaft, an upper end and a lower end.

Side Determination

- The upper end is broader and larger than the lower end.
- The medial and lateral sides of the bone can be distinguished by examining the lower end; this end has a prominent downward projection, the ***medial malleolus*** (Latin.malleo=hammer, malleolus=small hammer), on its medial side (Fig. 22.29).

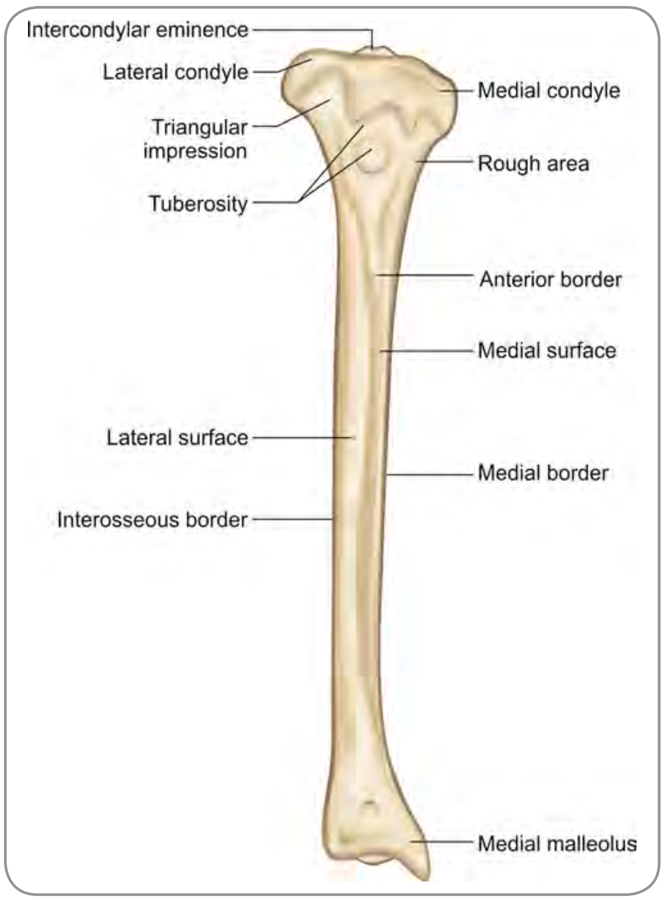


Fig. 22.29: Right tibia: anterior aspect

- The anterior and posterior aspects of the bone can be distinguished by examining the shaft. The shaft is triangular in section and has a sharp anterior border, which runs down from a prominent tibial tuberosity in the upper part.
  From this information, the side of the given tibia can be determined.

Upper End

The upper end of the tibia is expanded to form a mass that projects medially, laterally and posteriorly beyond the shaft When viewed from above, it is seen to consist of two parts called the ***medial*** and ***lateral condyles*** which are separated by an ***intercondylar area*** (Fig. 22.30).

The anterior aspect of the upper end of the tibia is marked by another projection called the ***tibial tuberosity***.

The upper surfaces of the medial and lateral condyles bear large, slightly concave, articular surfaces which take part in the formation of the knee joint. The medial articular surface is oval, and is larger than the lateral surface which is rounded. The central parts of the articular surfaces are slightly concave to receive the femoral condyles; the peripheral parts flatter and accommodate the menisci.

Intercondylar eminence: The articular surfaces are separated by the intercondylar area, which is non-articular. The intercondylar area is raised in its central part to form the ***intercondylar eminence*** (Fig. 22 30).

Intercondylar tubercle: The medial and lateral parts of the eminence are more prominent than its central part and constitute the medial and lateral ***intercondylar tubercles***. The medial and lateral condylar articular surfaces extend on to the sides of the intercondylar tubercles (Fig. 22.31).

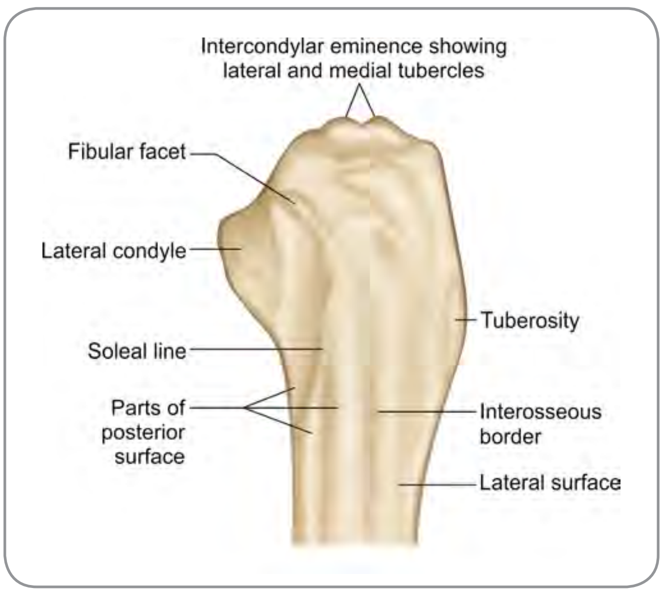


Fig. 22.30: Upper end of right t bia: lateral aspect

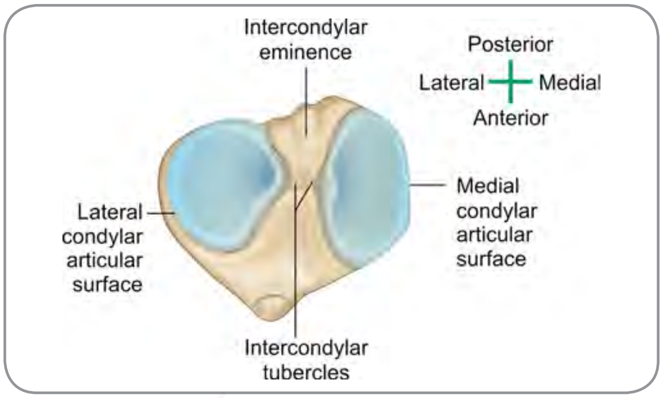


Fig. 22.31: Right tibia seen from above: a, b-medial and lateral intercondylar tubercles

In addition to its upper surface, the medial condyle has rough anterior, medial and posterior surfaces which are distinctly marked off from the shaft by a ridge. The posterior surface of the medial condyle is marked by a groove.

The lateral condyle has similar anterior, lateral and posterior surfaces. The posterolateral part of the lateral condyle bears an oval articular facet for the upper end of the fibula. The facet is directed backwards, downwards and laterally (Fig. 22.32).

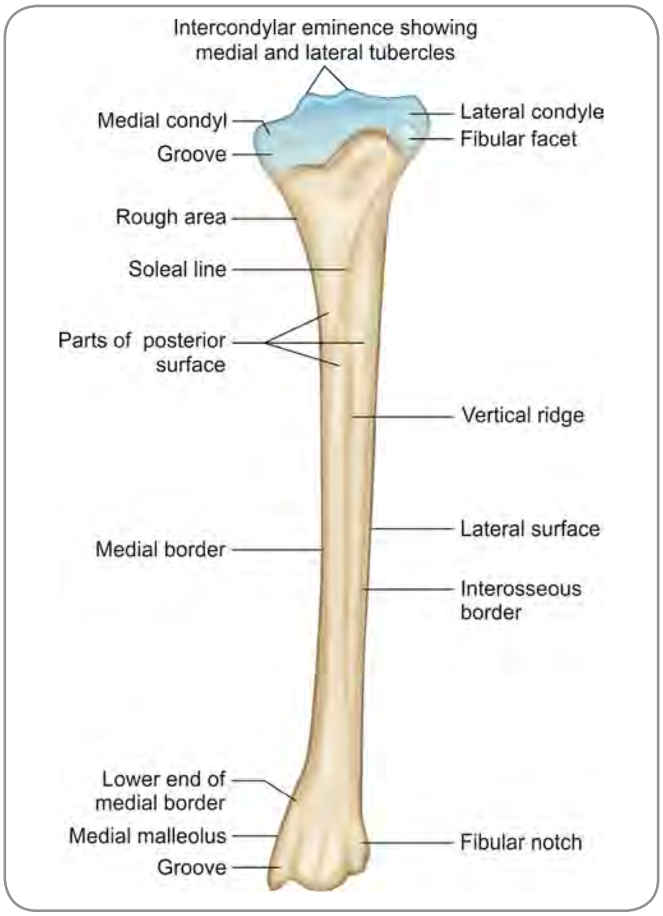


Fig. 22.32: Right tibia: posterior aspect

The anterior surfaces of the medial and lateral condyles merge to form a large rough triangular area. The apex of the triangle is placed inferiorly and is raised to form the ***tibial tuberosity***. The tuberosity has an upper smooth part and a lower rough part. The lateral margin of the triangle has a prominent impression (which is also triangular).

Shaft

The shaft is triangular. It has anterior, medial and lateral (or interosseous) borders and medial, lateral and posterior surfaces.

Borders: The ***anterior border*** runs downwards from the tibial tuberosity. Its lower part turns medially and reaches the anterior margin of the medial malleolus. The ***interosseous*** or ***lateral border*** begins a little below and in front of the articular facet for the fibula. It descends along the lateral aspect of the shaft. Its lower end forms the anterior margin of a rough triangular area seen on the lateral aspect of the lower end. The upper end of the ***medial border*** lies below the most medial part of the medial condyle. Its lower end becomes continuous with the posterior margin of the medial malleolus.

Surfaces: The ***medial surface*** lies between the anterior and medial borders. The upper end of the surface is rough just in front of the medial border. The rest of the surface is smooth and can be felt through the overlying skin (the shin of the tibia). Inferiorly, it becomes continuous with the medial surface of the medial malleolus. The ***lateral surface*** lies between the anterior and interosseous borders. Because of the fact that the anterior border turns medially in its lower part, the lateral surface extends onto the anterior aspect of the lower part of the shaft. The ***posterior surface*** (Fig. 22.32) lies between the medial and interosseous borders. Over the upper one-third of the shaft, this surface is marked by a prominent ridge that runs downwards and medially across it. This ridge is called the soleal line. The part of the posterior surface above the soleal line is triangular. The part below the soleal line is subdivided into medial and lateral parts by a faint vertical ridge. At the upper end of this ridge is the nutrient foramen of the bone.

Lower End

The lower end of the tibia is much less expanded than the upper end. Its medial part shows a downward projection called the ***medial malleolus***. The posterior aspect of the malleolus is marked by a prominent groove. The lateral aspect of the lower end shows a triangular ***fibular notch*** (Fig. 22.33) for articulation with the fibula. It consists of an upper part that is rough and a lower part that is smooth.

The inferior surface of the lower end bears an articular area that articulates with the upper surface of the talus to form the ankle joint. The area is continuous with another articular area on the lateral aspect of the medial malleolus that articulates with the medial side of the talus.

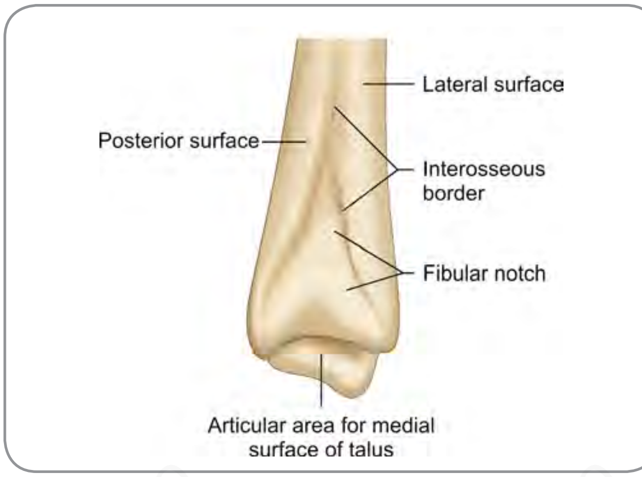


Fig. 22.33: Right tibia: lower end seen from the lateral side

Attachments of Various Structures

Muscular Insertions (Fig. 22.34 and 22.35)

- The pull of the ***quadriceps femoris*** is transmitted to the tibia through the ligamentum patellae that is attached to the smooth upper part of the tibial tuberosity The attachment may extend to the rough lower part of the tuberosity also.
- The ***sartorius***, the ***gracilis*** and the ***semitendinosus*** have linear vertical areas of insertion on the upper part of the medial surface. The area for sartorius, shaped like an inverted hockey stick, is the most anterior, that for semitendinosus, the most posterior and between the two is the area for gracilis. However, gracilis gets attached slightly higher to ***semitendinosus***.
- The ***semimembranosus*** is inserted into the posterior and medial aspects of the medial condyle.
- The ***popliteus*** is inserted into the posterior surface of the shaft, on the triangular area above the soleal line.

Muscular Origins

- The ***tibialis anterior*** arises from the upper two-thirds of the lateral surface of the shaft.
- The ***soleus*** arises from the soleal line, and from the middle one-third of the medial border of the shaft.
- The ***tibialis posterior*** arises from the upper two-thirds of the lateral part of the posterior surface of the shaft, below the soleal line.
- The ***flexor digitorum longus*** arises from the medial part of the posterior surface of the shaft below the soleal line.

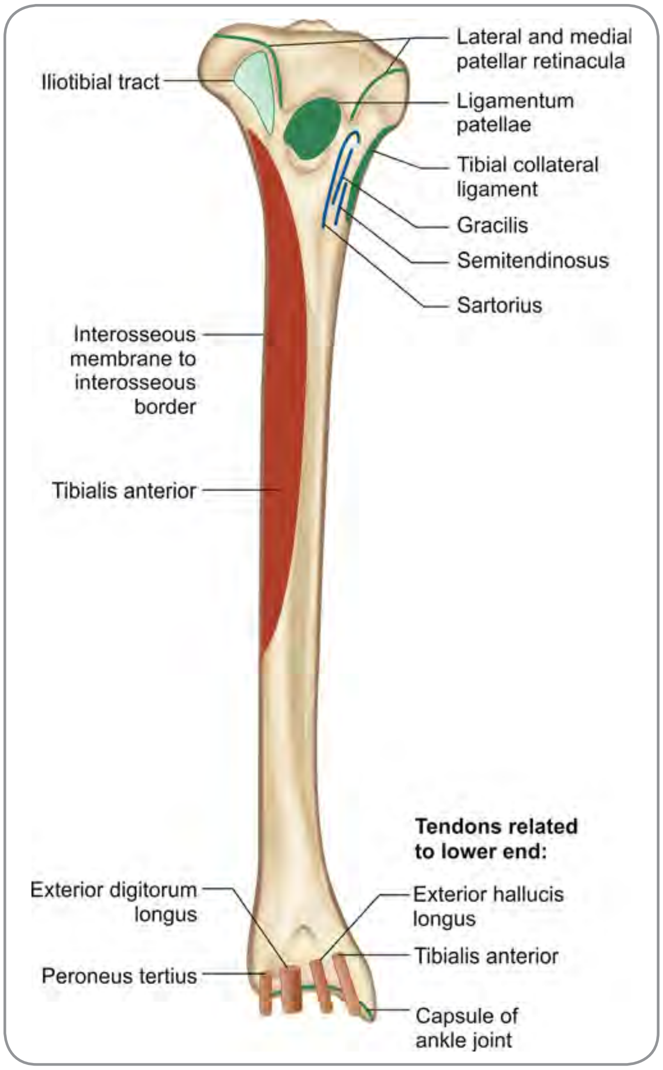


Fig. 22.34: Right tibia: showing attachments seen from the front

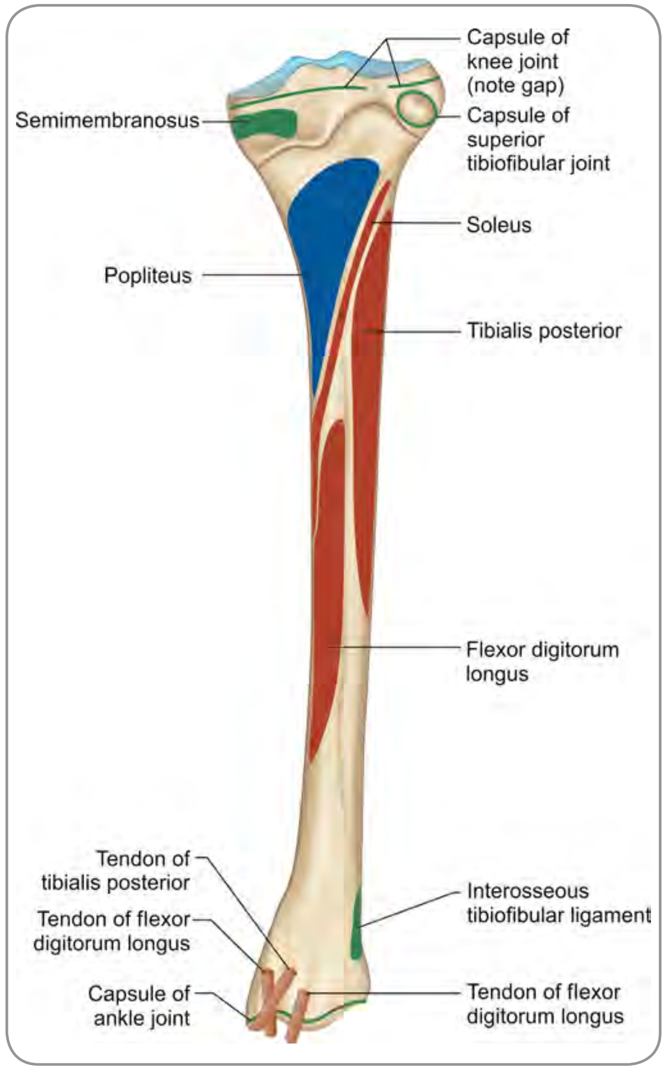


Fig. 22.35: Right tibia: showing attachments seen from behind

Attachments of Other Structures

- The ***capsular ligament of the knee joint*** is attached to the condyles of the tibia a little below the margins of the articular sufaces. In the region of tuberosity, the attachment of the capsule is replaced by that of the ligamentum patellae.
- The intercondylar area, on the superior aspect of the upper end of the tibia, has the following attachments (in anteroposterior sequence) (Fig. 22.36):
  - Anterior end of medial meniscus
  - Anterior cruciate ligament
  - Anterior end of lateral meniscus
  - Posterior end of lateral meniscus
  - Posterior end of medial meniscus
  - Posterior cruciate ligament
- The interosseous membrane that extends between the tibia and the fibula is attached to the interosseous border (Fig. 22.37).

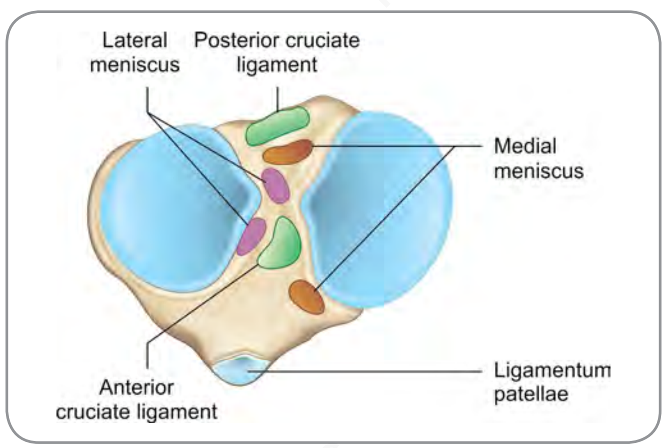


Fig. 22.36: Right tibia showing attachments: seen from above

- The deltoid ligament (medial ligament) of the ankle is attached to the apex of medial malleolus.

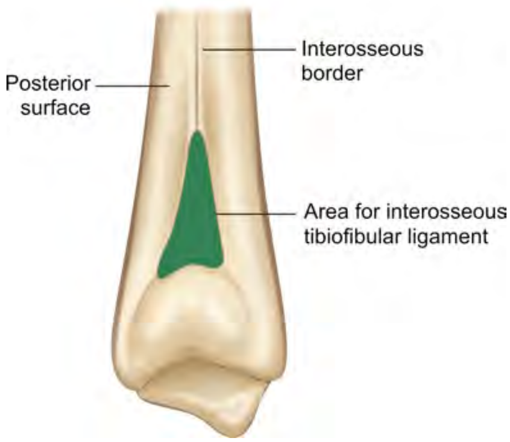


Fig. 22.37: Right tibia lower end, lateral aspect: showing the area for attachment of the interosseous t biofibular ligament

Added Information

- The anterior aspect of the lower end of the tibia (which is continuous with the lateral surface of the shaft) is crossed by the tendons (from medial to lateral side) of tibialis anterior, Extensor hallucis longus, extensor digitorum longus and Peroneus tertius.
- The anterior tibial vessels and the deep peroneal nerve cross the anterior aspect of the lower end of the bone lying between the tendons of the extensor hallucis longus and the extensor digitorum longus.
- The posterior aspect of the lower end of the tibia is crossed by tendons (from medial to lateral side) of Tibialis posterior, Flexor digitorum longus and Flexor hallucis longus. The tendon of the flexor digitorum longus crosses that of the tibialis posterior near the lower end of the bone. The tibialis posterior tendon often grooves the posterior surface of the medial malleolus.
- The posterior tibial vessels and nerve cross the posterior aspect of the lower end of the bone lying between the tendons of the flexor digitorum longus and the flexor hallucis longus.
- The superior surface of the medial condy e has an oval articular area for articulation with the medial condyle of femur and the medial meniscus.
- The superior surface of the lateral condyle has a circular articular area for articulation with the lateral condyle of femur and the lateral meniscus.
- The anterolateral aspect of the lateral condyle has a smooth rounded facet for the attachment of the iliotibial tract; the facet is referred to as the ***Gerdy's tubercle*** or the ***anterolateral tibial tubercle***.
- The linear insertions of the sartorius, gracilis and semitendinosus cause a pattern resembling the foot of the goose Hence, this is referred to as 'pes anserinus (Greek. pes=foot, Latin.anser=goose).
- The great saphenous vein and the saphenous nerve cross the lower part of the medial surface.

Ossification

The tibia has three centres of ossification.

- The primary centre for the shaft appears in the 7th week of foetal life.
- A secondary centre for the upper end appears towards the end of foetal life. This centre includes the tibial tuberosity. Ossification extends into the tuberosity from the 10th year. The epiphysis fuses with the shaft between the 16th and 18th years (a separate centre may sometimes exist for the tibial tuberosity).
- Another secondary centre for the lower end appears during the first year and fuses with the shaft between the 15th and 17th years.

Clinical Correlation

- The shin and anterior border are used as resources of bone for bone grafting.
- In children, upper part of the shin is the preferred site for marrow puncture.
- The upper articular surfaces of the tibia may be poorly formed resulting in congenital dislocation of the knee.
- The upper end is the growing end. The nutrient foramen points inferiorly.
- The tibia is narrowest at the junction of the middle and inferior thirds and this area has the poorest blood supply. So, this area is more prone to fractures.
- Unaccustomed powerful contraction of the anterior leg muscles can lead to fractures to the anterior cortex of the tibia. Inferior third of the bone is commonly involved and these are called the transverse march or straws fracture

FIBULA

***Other names*:** Brooch bone, splint bone, calf bone, Os peroneum

The fibula (Latin.figo=to fix Figibula=a buckle or a brooch) is the lateral bone of the leg. It is a slender bone with slightly expanded ends and a twist. It has a ***shaft***, an ***upper end*** (or ***the head***) and a ***lower end*** (or the ***lateral malleolus***). Both the head and the lateral malleolus can be felt subcutaneously (Fig. 22.38 to 22.43).

Side Determination

- The upper end is irregularly expanded in all directions. In contrast, the lower end is flattened from side-to-side and forms the ***lateral malleolus***.
- The medial side of the malleolus bears a triangular articular surface for the talus
- Posterior to this articular surface the malleolus shows a deep ***malleolar fossa*** and this fact enables the anterior and posterior aspects of the bone to be distinguished from one another.

  The side to which a fibula belongs can be determined with the help of this information.

Upper End

The upper end of the fibula is also called the ***head***. It is approximately cuboidal. Its posterior and lateral part shows an upward projection called the ***styloid process*** (also called the apex of the head). In front of, and medial to, the styloid process, the head shows a circular facet for articulation with the tibia (to form the superior tibiofibular joint). The facet is directed upwards and medially.

The part of the bone immediately below the head is called the ***neck*** (Figs 22.38 and 22.39).

Shaft

The surfaces and borders of the shaft show considerable variation from bone to bone and may be difficult to identify. However, the shaft is almost completely surrounded by muscles.

It has three borders, namely the—(1) anterior, (2) posterior and (3) interosseous (or medial) and three surfaces, namely—(1) lateral, (2) medial and (3) posterior.

- The ***anterior border*** is sharp. Though it begins jus below the anterior aspect of the head, it is identifiable only at its inferior aspect. Near to its lower end, it turns laterally to join the apex of the subcutaneous triangular area of the shaft above the lateral malleolus. The lowest part of the anterior border forms the posterior margin of the triangle. The triangle itself is indicative of the inferior end of the shaft, the anterior border and the lateral aspect of the bone.
- The upper end of the ***posterior border*** lies in line with the styloid process. Its lower end reaches the medial part of the posterior surface of the lateral malleolus.
- The ***interosseous border*** lies very near to the anterior border and may be indistinguishable from the latter in the upper part of the shaft. When traced downwards, it passes medially and merges with the upper part of the rough area above the talar facet of the lateral malleolus.
- The ***lateral surface*** lies between the anterior and posterior borders. Because of the lateral inclination of the lower part of the anterior border, the lower part of the

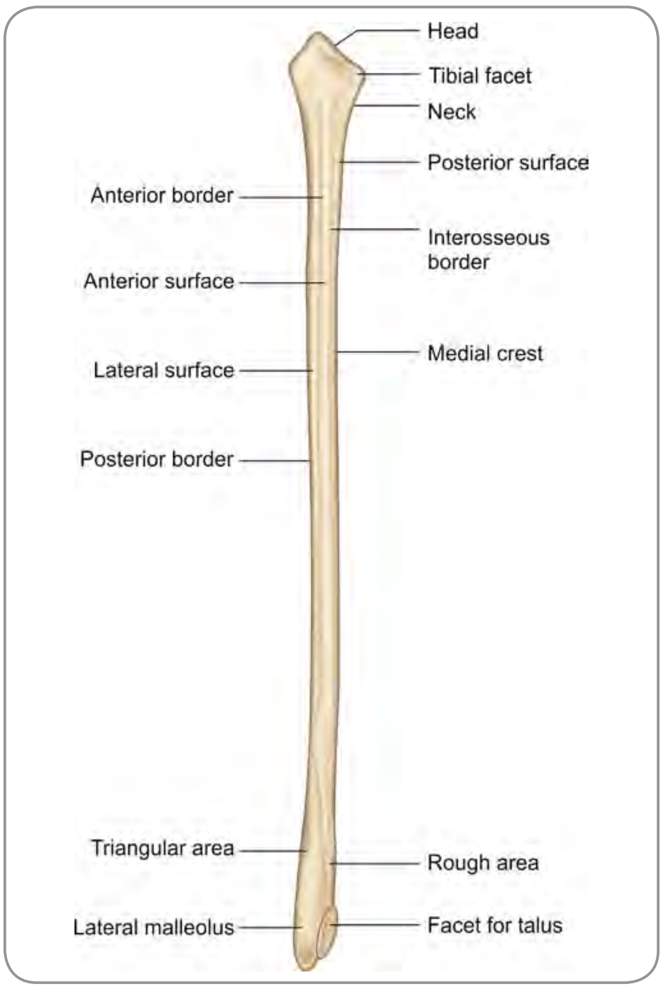


Fig. 22.38: Right fibula: seen from the front

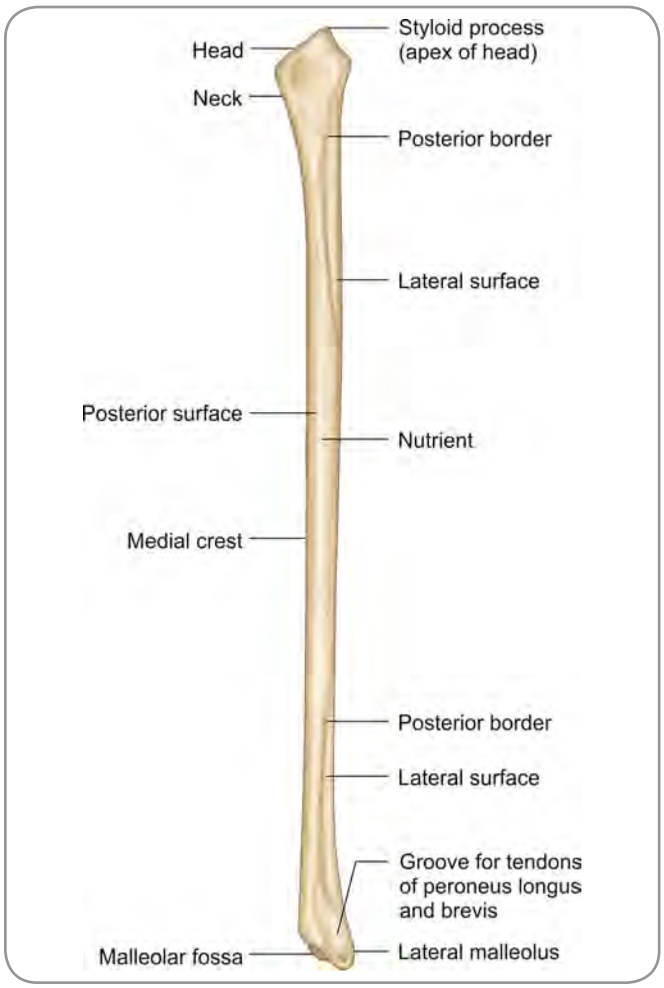


Fig. 22.39: Right fibula: seen from behind

lateral surface faces backwards and becomes continuous with the posterior aspect of the lateral malleolus.

- The ***medial surface*** (also called the anterior surface) lies between the anterior and interosseous borders. It is very narrow in the upper half of the shaft. Its lower broader part faces as much forwards as medially, therefore, giving it the name ***anterior surface***.
- The ***posterior surface*** lies between the interosseous and posterior borders. It occupies a very large area of the surface of the shaft. Over its upper three-fourths, it is divided into two distinct parts, medial and lateral, by a vertical ridge called the ***medial crest*** (or the peroneal crest). This ridge, which runs down from the neck for two-thirds of the bone's length, is more prominent than the interosseous or posterior borders. In the lower part it curves forwards to join the interosseous border. The nutrient foramen (Fig. 22.39) of the bone is found near the median crest. The medial part of the posterior surface is deeply concave and faces forwards and medially. The flat lateral part of the posterior surface faces posteriorly in its upper part and medially in its lower part. The lowest part of the posterior surface lies just above the talar facet of the lateral malleolus. This part is roughened for attachment of a strong ligament that connects the fibula to the tibia.

Fig. 22.40: Right fibula: showing attachments seen from the front

Lower End

The lower end of the fibula is called the ***lateral malleolus***. It has a convex lateral surface that can be felt through the overlying skin. This surface is continuous above with a triangular area on the shaft (Fig. 22.39).

The medial surface of the malleolus bears a triangular facet, the apex of the triangle being directed downwards This facet articulates with the lateral surface of the talus and forms part of the ankle joint. Just above the facet, the lower part of the shaft shows a rough area. Behind the facet, the medial surface of the malleolus shows a deep ***malleolar fossa***.

The lower end also has a posterior surface which has a shallow groove on it.

It may be noted that the lateral malleolus projects to a lower level than the medial malleolus (of the tibia).

Attachments of Various Structures

Though the fibula as such is a slender bone, several muscles are attached to it. The bone itself lies submerged in muscular tissue and is moulded into a twisted shape because of the muscles.

Muscular Insertions

The ***biceps femoris*** is inserted into the head of the fibula. The attachment is through two separate slips which are separated by the fibular collateral ligament of the knee joint (Fig. 22.40).

Muscular Origins (Figs 22.40 to 22.42)

- The narrow medial surface gives origin to the ***extensor digitorum longus*** from the upper three-fourths, the ***peroneus tertius*** from an area below that for the extensor digitorum longus, the ***extensor hallucis longus*** from the middle two-fourths, medial to the origin of the extensor digitorum longus.
- The lateral surface gives origin to the ***peroneus longus*** from the upper two-thirds and the ***peroneus brevis*** from the lower two-thirds. Part of peroneus longus also arises from the lateral aspect of the head of the fibula; the common peroneal nerve lies between the two areas of origin.
- The posterior surface gives origin to the ***tibialis posterior*** from the upper two-third of its medial part, the ***soleus*** from the upper one-fourth of its lateral part and the ***flexor hallucis longus*** arises from the lower two-thirds of its lateral part Soleus also takes origin from the posterior aspect of the head.

Attachments of Other Structures

- The fibular collateral ligament of the knee joint is attached to the styloid process.

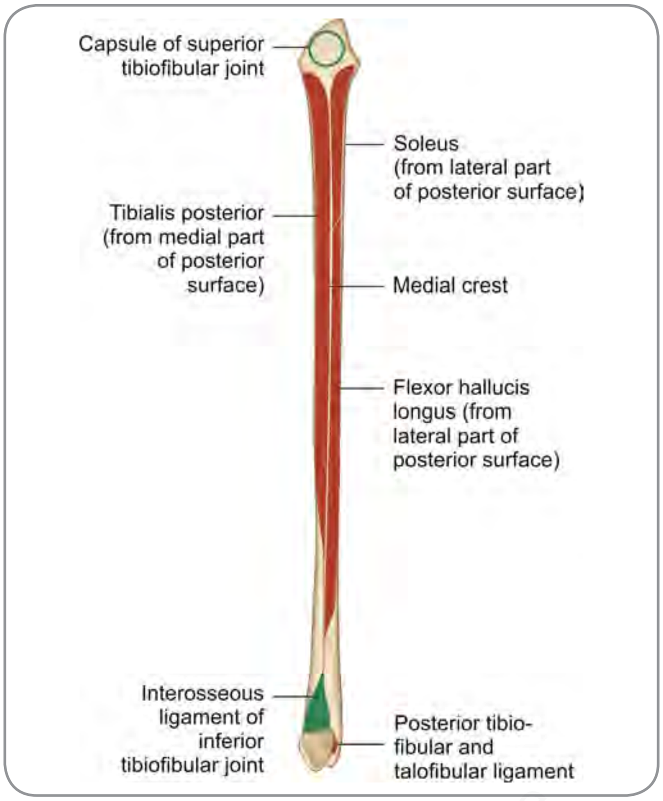


Fig. 22.41: Right fibula: showing attachments seen from the medial side

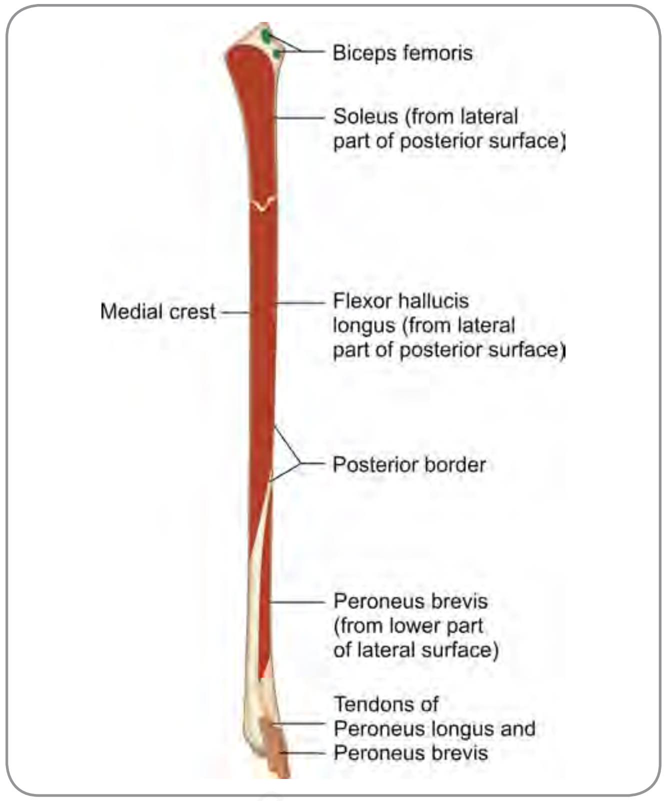


Fig. 22.42: Right fibula: showing attachments seen from behind

- The interosseous membrane is attached to the interosseous border.
- The anterior and posterior intermuscular septa get attached to the anterior and posterior borders respectively.

Additional Notes

- The common peroneal nerve winds round the lateral aspect of the neck of the fibula.
- The tendons of the peroneus longus and the peroneus brevis pass downwards just behind the lateral malleolus.
- The peroneal artery is closely related to the medial crest.

Ossification

The fibula has three centres of ossification.

- The primary centre, for the shaft, appears in the 8th foetal week.
- A secondary centre for the upper end appears in the 3rd or 4th year and fuses with the shaft between the 17th and 19th years
- A secondary centre for the lower end appears in the first year and fuses with the shaft between the 15th and 17th years

Exception to the rule: By the law of ossification, the secondary centre that appears first is the last to fuse and the one to appear last is the first to fuse. All the long bones except the fibula abide by the law. The fibula is an exception in that the centre that appears first for the lower end) is also the first to fuse.

Clinical Correlation

- The fibula is the commonly used bone for taking pieces for bone grafting. The graft piece is usually taken close to and along with the nutrient foramen so that it is easy to establish a good blood supply to the grafted piece in its new location.
- The upper end is the growing end. The nutrient artery is directed inferiorly
- Fibular fractures are frequently associated with tibial fractures and dislocations of the ankle joint. They are very painful due to disrupted muscular attachments.

In most fibular fractures, walking is compromised because of the bone's role in ankle stability.

Fractures of the Tibia and Fibula

- Fractures of the bones of the leg are commonly seen in motorcycle accidents.
  - The tibia may be fractured through a condyle (usually lateral), through the shaft, or through the medial malleolus;
  - Fracture of the shaft of the tibia is usually accompanied by a corresponding fracture of the fibula;
  - The fibula may also be fractured through the lateral malleolus.

contd...

Clinical Correlation *contd...*

- Injuries to the tibia and fibula in the region of the ankle are referred to as ***Pott's fracture*** which can be of several types
  - Forceful abduction or lateral rotation of the foot can lead to a fracture of the lateral malleolus;
  - Once this malleolus is broken, the injuring force acts on the medial ligament of the ankle joint leading to its rupture, or to its avulsion along with the tip of the medial malleolus (***avulsion fracture*** of the medial malleolus).
- More severe injury can lead to disorganisation of the ankle joint as a result of rupture of the interosseous tibiofibular ligament or as a result of fractures through both malleoli. In such injury, the fibula is sometimes fractured th ough the lower part of its shaft.
- Forcible adduction and medial rotation of the foot can lead to fracture of the medial malleolus; and rupture of the lateral ligament or avulsion fracture of the lateral malleolus.
- Blood supply to the tibia is poor at the junction of the upper two-thirds and lower one-third of the shaft. Fractures here may, therefore, show delayed union or non-union.

SKELETON OF FOOT

The skeleton of the foot consists of the tarsus, metatarsus and the phalanges (Figs 22.43 and 22.44).

The term ***tarsus*** (Greek.tarsos=flat) indicates the group of seven short bones in the posterior part of the foot. They are so arranged that one of them, the talus, articulates with the tibia and fibula above and rests on the base formed by the rest of the tarsal bones below. The talus, along with the lower ends of the tibia and fibula forms the ankle joint.

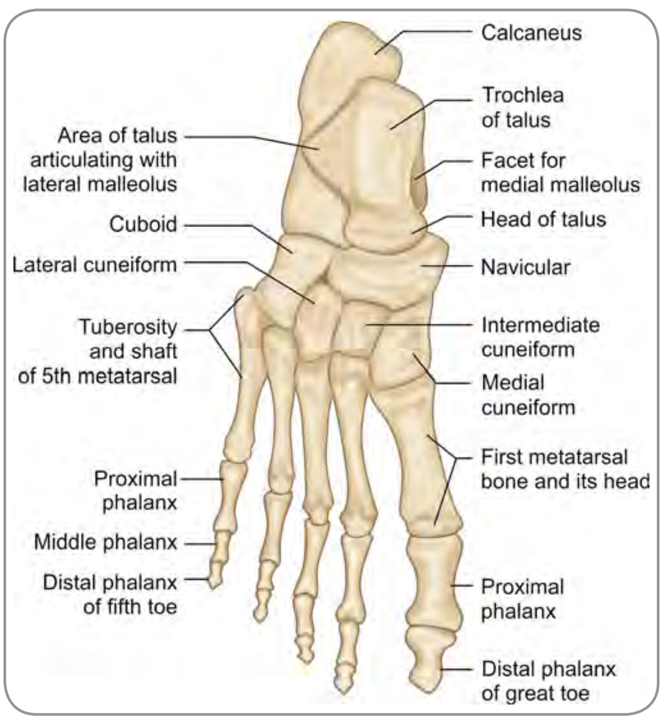


Fig. 22.43: Skeleton of the foot seen from above (dorsal aspect)

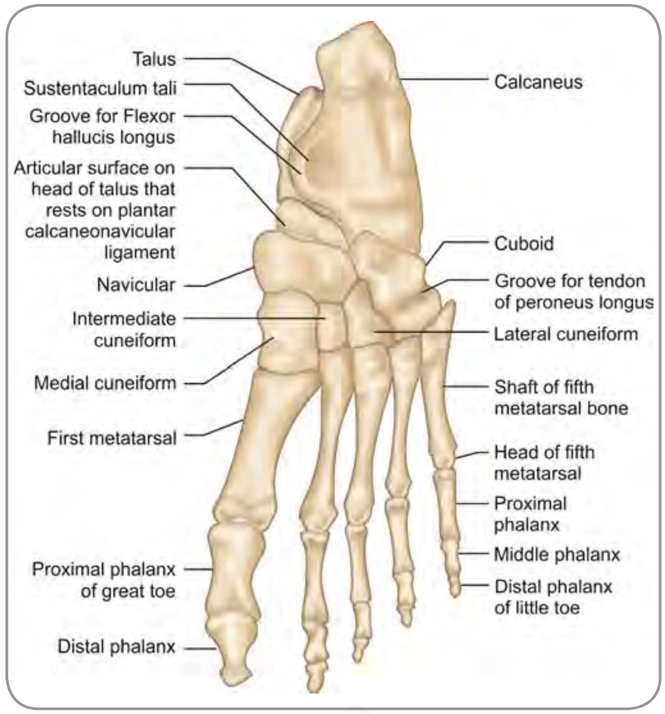


Fig. 22.44: Skeleton of the foot seen from below (plantar aspect)

Articulating with the talus on its inferior aspect is the largest tarsal bone called the ***calcaneus.*** It is the bone that forms the heel

Anterior (or distal) to the calcaneus and the talus are two bones of intermediate size. These are the ***navicular*** placed medially, and the ***cuboid*** placed laterally. Distal to the navicular are three smaller bones. These are the cuneiforms, individually called the ***medial cuneiform***, the ***intermediate cuneiform***, and the ***lateral cuneiform***.

Anterior to the tarsal bones are the five ***metatarsal bones***. Distal to the metatarsal bones are the ***phalanges***: three (proximal, middle, distal) for each digit except the great toe which has only two phalanges, proximal and distal.

TARSAL BONES

Talus

Other names: Ankle bone, astragalus

As already noticed, the ***talus*** (Latin.talus=ankle) forms the ankle by articulating with the tibia and fibula. It also articulates with the calcaneus and the navicular to provide for the movements of the foot as a whole.

Side Determination

- The bone is elongated anteroposteriorly. The anterior end (or head) can be distinguished from the posterior end as it is rounded and has a large convex articular surface.

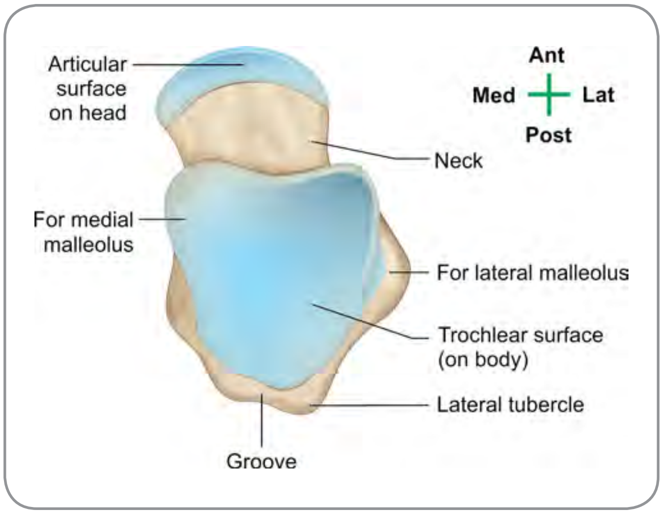


Fig. 22.45: Right talus: seen from above

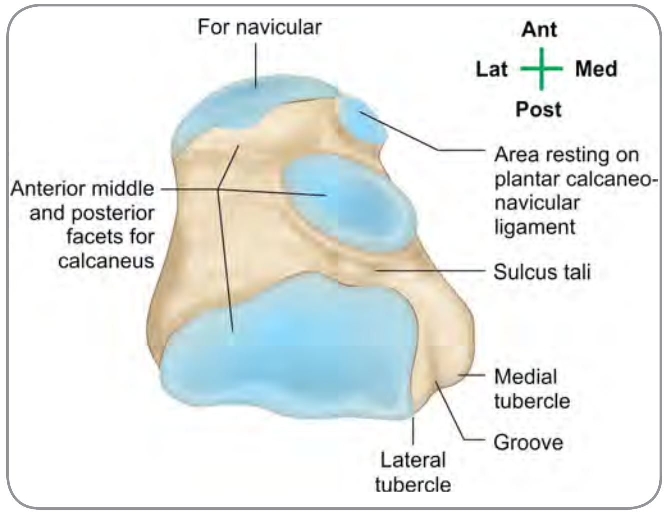


Fig. 22.47: Right talus: seen from below

- The superior aspect of the bone bears a large pulley-shaped surface that is convex upwards. The inferior aspect bears three facets.
- The lateral surface bears a large triangular facet, while the medial side shows a 'comma'-shaped facet.

  With these details, the side of any given talus can be determined.

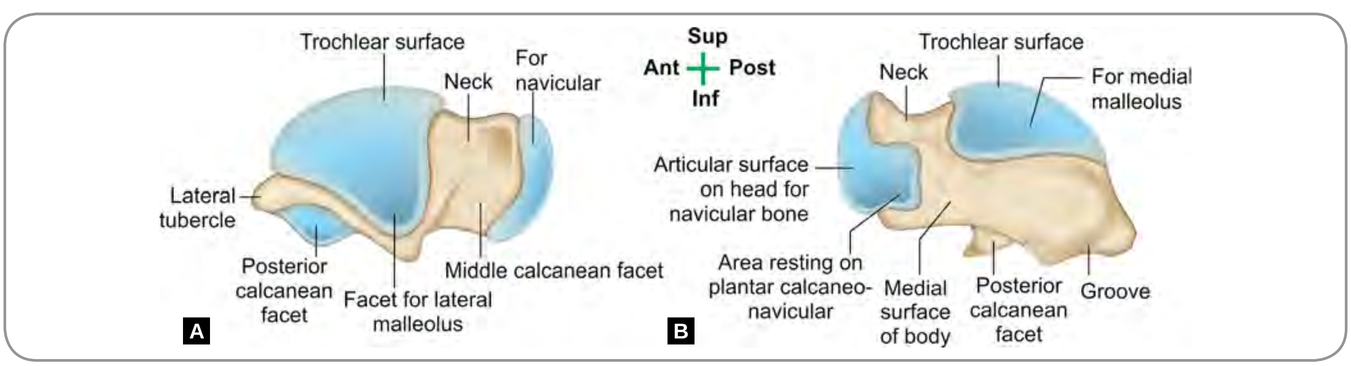
The bone has a ***head***, a neck and a ***body.*** The distal surface of the head has a large convex surface that articulates with the navicular bone (Fig 22.45).

The upper surface of the body is covered by a large ***trochlear articular surface*** which articulates with the lower end of the tibia. This surface is convex from front to back, and concave from side to side. The trochlea is narrower at its posterior end than the anterior end. The ***lateral surface*** (Fig. 22.46A) of the body bears a large triangular facet for articulation with the lateral malleolus of the fibula, while the ***medial surface*** (Fig. 22.46B) bears a ***comma-shaped*** facet that is broad anteriorly and tapers off posteriorly. This facet articulates with the medial malleolus of the tibia.

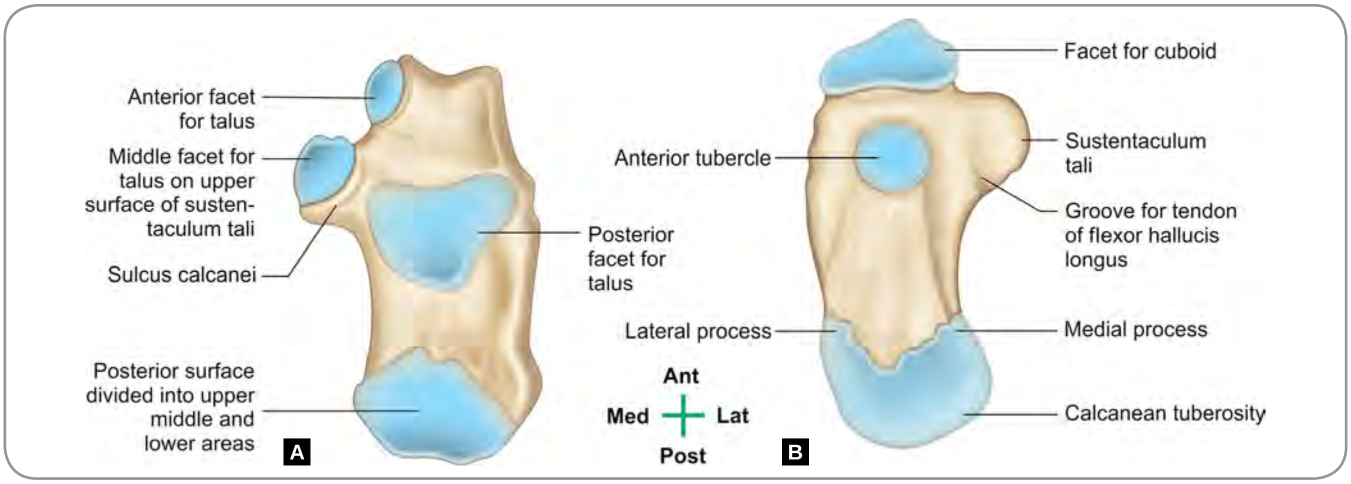
The lower and posterior part of the body of the talus projects backwards. This projection is called the ***posterior process***. A groove divides this process into ***medial and lateral tubercles***. The lateral tubercle may be seen as a separate bone, in which case, it is called the ***os trigonum***.

The articular area on the head, for the navicular bone, extends onto the ***inferior aspect*** of the head. Behind this, on the inferior surface are three facets, ***anterior***, ***middle*** and ***posterior***, for articulation with corresponding facets on the upper surface of the calcaneus. The middle and posterior facets are separated by a deep groove called the ***sulcus tali***. Along with the sulcus calcanei (of the calcaneus), the sulcus tali forms the ***sinus tarsi***. Medial to the anterior calcaneal facet, the lower aspect of the head of the talus has an area that rests on the plantar calcaneonavicular ligament (Fig. 22 47).

The neck is slightly twisted and projects inferomedially. The angle between the axes of the body and the neck is about 18 degrees. The angle is more in infants and less in old age. It is very much increased in cases of varus (club foot) deformities.



Figs 22.46A and B: A. Right talus: seen from the lateral side **B.** Right talus: seen from the medial side



Figs 22.48A and B: A. Right calcaneus seen from above **B.** Right calcaneus seen from below

Calcaneus

Other name: Heel bone

The ***calcaneus*** (Greek.calcaneo=heel) is the most posterior and the largest of the tarsal bones. In its normal position, its anterior end is at a slightly higher level than its posterior end, thus contributing to the longitudinal arch of the foot.

Side Determination

- The bone is elongated anteroposteriorly The anterior aspect is easily distinguished from the posterior as it is covered by a large articular facet, while the posterior aspect is non-articular.
- The superior aspect can be distinguished from the inferior as it bears three facets, while the inferior aspect is non-articular.
- The medial aspect can be distinguished from the lateral aspect as it bears a prominent shelf-like projection.

With these details, the side of a given calcaneus can be established.

The calcaneus has—(1) ***anterior***, (2) ***posterior***, (3) ***medial***, (4) ***lateral***, (5) ***superior*** and (6) ***inferior*** surfaces

- The ***anterior surface*** is fully covered by a large, concavoconvex articular facet for the cuboid bone.
- The ***posterior surface*** is non-articular. It is divisible into upper, middle and inferior parts. The upper part is smooth, the middle is jagged and the inferior is sloping forward. The inferior part of the posterior surface transmits the weight of the body from the heel to the ground.
- The ***medial surface*** is easily distinguished by the presence of a large shelf-like projection that projects medially from its anterior and upper part. This projection is the ***sustentaculum tali*** (Latin.sustentaculo=shelf; talar shelf)**.** The inferior aspect of the sustentaculum tali is marked by a groove.
- The ***lateral surface*** is more or less flat. Its anterior part shows a small elevation called the ***peroneal trochlea*** (or ***tubercle***). The anterosuperior and the posteroinferior aspects of the tubercle are grooved.
- The ***superior or dorsal surface*** bears three facets, namely the anterior, middle and posterior facets which articulate with corresponding facets on the inferior surface of talus. The middle of these facets lies on the upper surface of the sustentaculum tali. It is separated from the posterior facet by a deep groove called the ***sulcus calcanei***. In the articulated foot, the sulcus calcanei comes into apposition with a similar groove on the talus (called the sulcus tali), to form a small tunnel called the ***sinus tarsi*** (Fig. 22.48A).
- The ***inferior or plantar surface*** of the calcaneus shows a prominence in its posterior part called the ***calcaneal tuberosity (***also called the ***tuber calcanei)***. The medial and lateral parts of tuberosity extend further forwards than its central part and are called the ***medial and lateral processes*** (sometimes, the medial and lateral tubercles) respectively of the tuberosity. The anterior part of the plantar surface shows another elevation called the ***anterior tubercle*** (Fig. 22.48B).

Navicular

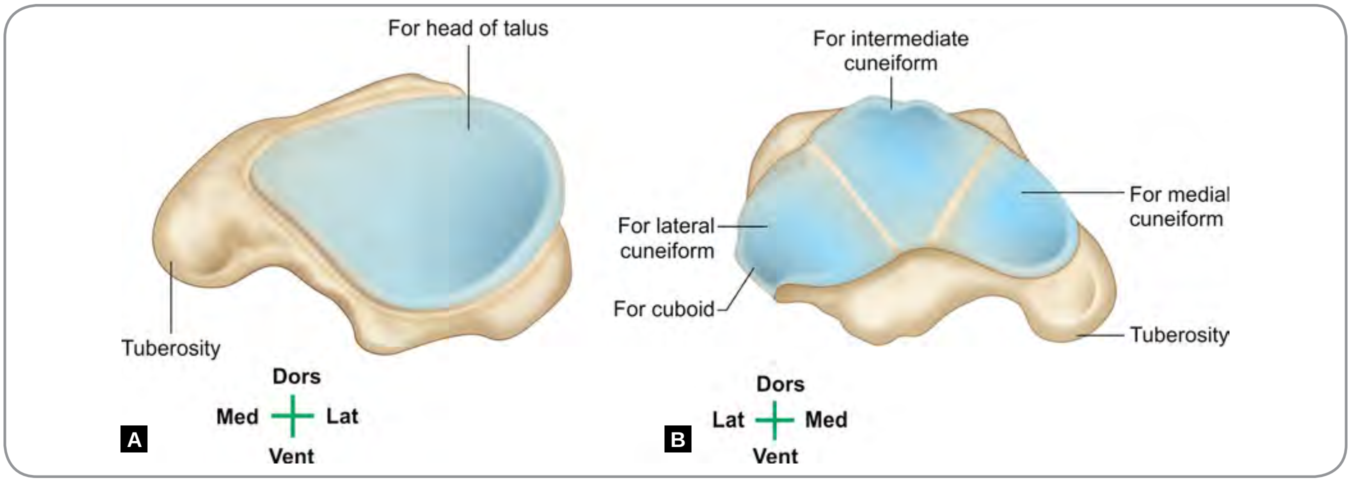
Other names: central bone of foot, scaphoid of foot

The navicular (Latin.navicular=little ship) bone, so called due to its boat shape, forms the anteroinferior part of the tarsus

Side Determination

- The posterior or proximal surface is covered by a single large concave articular facet for the head of the talus.
- The superior or dorsal surface is convex, while the inferior or plantar surface is concave. Both surfaces are rough.
- The medial aspect of the bone has a projection that appears to hang inferiorly and is called the ***tuberosity***.

With this information, the side of the given navicular bone can be determined.



Figs 22.49A and B: Right navicular bone **A.** Proximal aspect **B.** Distal aspect

It is customary to describe the navicular to have a posterior surface, an anterior surface, a superior surface, an inferior and a medial aspect. The bone articulates proximally with the head of the talus, distally with the three cuneiform bones, and laterally with the cuboid.

The posterior surface (also called the proximal surface) is deeply concave and has a single articular facet to fit the convexity of the head of talus. The anterior surface (also called the distal surface) is also articular. The articular facet is separated into three distinct areas by ridges; the three areas are arranged in a curve to articulate with the three cuneiforms (Fig. 22.49A).

The superior surface (also called the dorsal surface) is rough, has several vascular foramina and merges imperceptibly with the medial and lateral aspects, forming a curved surface that conforms to the curve of the dorsum of foot. The inferior surface (also called the plantar surface) is also rough and slopes up anteriorly to reach the proximal surface. The medial part of the bone has a projection called tuberosity, which can be felt about 3–4 cm below and in front of the medial malleolus. The lateral aspect may have an articular facet for the cuboid bone (Fig. 22.49B).

Cuboid

This bone is so named from its cubical shape. It forms the anterolateral aspect of the tarsus

Side Determination

- Though both the anterior and posterior surfaces of the bone are articular, the anterior surface is almost flat while the posterior is concavoconvex.
- The superior surface is rough and flat; the inferior surface has a prominent ridge across itself and a groove adjacent to the ridge.
- The medial surface has an articular facet for the lateral cuneiform and the lateral surface is rough with a tuberosity on its posterior aspect and a groove immediately anterior to the tuberosity.

The cuboid bone articulates proximally with the calcaneus; distally with the fourth and fifth metatarsal bones, and medially with the navicular and lateral cuneiform bones. It has six surfaces, namely the anterior, posterior, superior, inferior, medial and lateral surfaces. The nearly flat anterior surface articulates with the bases of fourth and fifth metatarsal bones by two articular facets which are separated by a ridge. The posterior surface is also articular but has a single large concavoconvex articular facet for articulation with the calcaneus.

The superior surface is rough and slopes down laterally to conform to the shape of the dorsum of foot. The inferior surface narrows posteriorly and has a prominent ridge. The lateral end of the ridge forms a projection called tuberosity; the ridge passes forwards and medially across the surface. Immediately anterior to the ridge is a groove which lodges the tendon of peroneus longus in life. This groove extends to the lateral aspect of the bone.

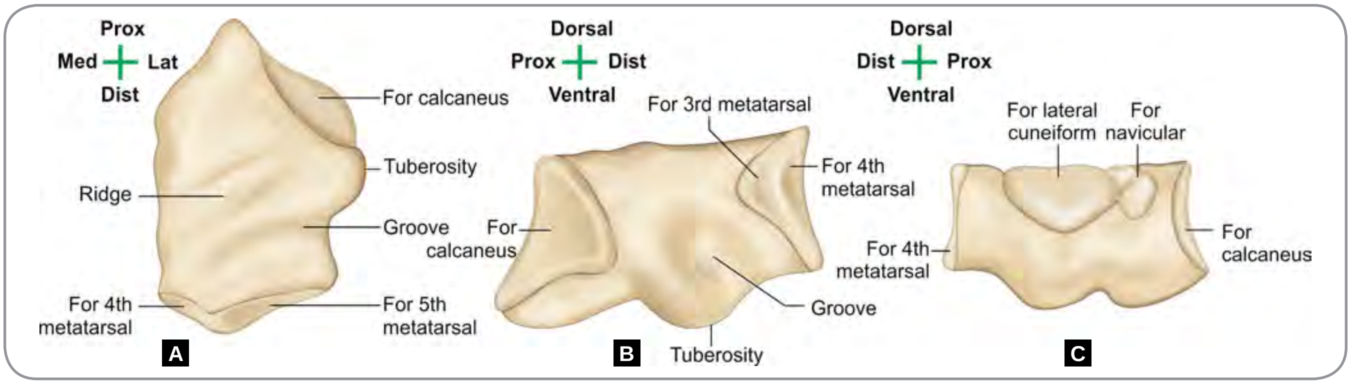
The medial surface faces upwards and medially; as this surface articulates with lateral cuneiform, the two bones together support the transverse arch of the foot. There may be an additional facet for the navicular bone (Figs 22.50A to C).

Cuneiforms

The cuneiforms (Latin.cuneus=wedge) are three in number and are ***wedge-shaped***, the ***intermediate*** and ***lateral*** cuneiforms being distinctly so. The three bones articulate with the navicular posteriorly and the first three metatarsals anteriorly. The shortness of the intermediate cuneiform makes the base of the second metatarsal project back between the medial and lateral cuneiforms.

Medial Cuneiform

The medial cuneiform bone is the largest of the cuneiform bones. It articulates proximally with the navicular bone, distally with the first metatarsal bone, and laterally with the intermediate cuneiform and second metatarsal bones.



Figs 22.50A to C: Right cuboid bone **A.** Plantar aspect **B.** Lateral aspect **C.** Medial aspect

Side determination

- The superior surface is narrower than the inferior surface. Both are non-articular.
- The posterior end bears a piriform facet, while the anterior surface bears a kidney-shaped facet.
- The medial surface is non-articular, while the lateral surface bears articular areas for the intermediate cuneiform and second metatarsal bones. The side of a given medial cuneiform can be determined with afore-mentioned information.

The convex medial surface and a large kidney-shaped articular facet on the anterior surface are specific to the medial cuneiform. Its superior, medial and inferior aspects run into each other to form a curved surface which conforms to the curve of the medial side of foot. The bone can be described to have an anterior, posterior, medial and lateral surfaces. The anterior surface shows a large kidney-shaped facet, which is often subdivided by a groove; this facet is for articulation with the base of the first metatarsal. The posterior surface has a small pear-shaped concave facet for articulation with the navicular. The lateral surface has an L-shaped articular facet for articulation with the intermediate cuneiform.

Intermediate Cuneiform

The intermediate cuneiform bone is the smallest of the cuneiform bones. It is shaped like a typical wedge. It articulates proximally with the navicular bone, distally with the second metatarsal bone medially with the medial cuneiform bone, and laterally with the lateral cuneiform bone.

Side determination

- The superior surface is wide, while the inferior surface is narrow.
- The medial surface bears an L-shaped facet, while the lateral side bears a vertical facet.
- The posterior and anterior aspects are both fully covered by triangular facets.

The side of a given intermediate cuneiform can be determined with the information given above.

The base of the wedge of intermediate cuneiform is on the superior aspect. The bone has ***superior***, ***inferior***, ***anterior***, ***posterior***, ***medial*** and ***lateral*** surfaces. The superior surface is square in outline and rough. The ***inferior*** surface is narrow. The ***anterior*** (or ***distal***) surface has a triangular articular facet that articulates with the base of the second metatarsal bone. The ***posterior*** (or ***proximal***) surface has a triangular articular facet which is concave and articulates with the navicular bone. The ***medial*** surface has an L shaped articular facet for articulation with the medial cuneiform. The lateral surface has a concave vertical facet for the lateral cuneiform, which is placed along the proximal border. The distal part of the lateral surface is non-articular.

Lateral Cuneiform Bone

This also is a wedge-shaped bone with the base being superior. The lateral cuneiform bone articulates proximally with the navicular bone, distally with the third metatarsal bone, medially with the intermediate cuneiform and second metatarsal bones; and laterally with the cuboid and fourth metatarsal bones.

Side determination

- The dorsal surface is wider than the plantar surface.
- The proximal and distal surfaces can be distinguished by the fact that the entire distal surface is covered by a triangular facet, but the proximal surface is covered by a smaller facet.
- Though both the medial and lateral surfaces bear facets, they are larger and more prominent on the medial aspect.

The bone has ***superior***, ***inferior***, ***anterior***, ***posterior***, ***medial*** and ***lateral*** surfaces. The ***superior*** and ***inferior*** surfaces are rough. The ***posterior*** surface has an oval concave facet which is confined to the dorsal two-thirds of the surface for articulation with the navicular. The

anterior surface has a triangular articular facet which articulates with the third metatarsal. This articular facet may be prolonged to the medial and lateral aspects where they would articulate with the second and the fourth metatarsals respectively. The ***posterior*** part of the medial surface has an articular facet for the intermediate cuneiform while the posterior part of the lateral surface has a round facet for the cuboid bone.

METATARSAL BONES

These are five in number, being numbered from medial to lateral side (in contrast to the metacarpal bones which are numbered from lateral to medial side). They are miniature long bones with a base (or proximal end), a shaft and a distal end or head. The head is rounded. The base is enlarged and has ***proximal***, ***dorsal***, ***plantar***, ***medial*** and ***lateral*** surfaces. The shaft is slightly convex on its dorsal side and concave on the plantar side. The first metatarsal is shorter than the rest but is much stronger and does not taper like the others

The head of each metatarsal bone articulates with the proximal phalanx of the digit concerned. The articulations of the bases of the metatarsal bones are as follows (Fig. 22.51)

- The first metatarsal bone has a large kidney-shaped facet on the proximal surface of its base. This facet articulates with the medial cuneiform bone.
- The base of the second metatarsal bone articulates
  - Proximally with the intermediate cuneiform bone,
  - Medially with the medial cuneiform bone and
  - Laterally with the lateral cuneiform bone and with the base of the third metatarsal bone.
- The base of the third metatarsal bone articulates
  - Proximally with the lateral cuneiform bone,
  - Medially with the second metatarsal bone and
  - Laterally with the fourth metatarsal bone.
- The base of the fourth metatarsal bone articulates

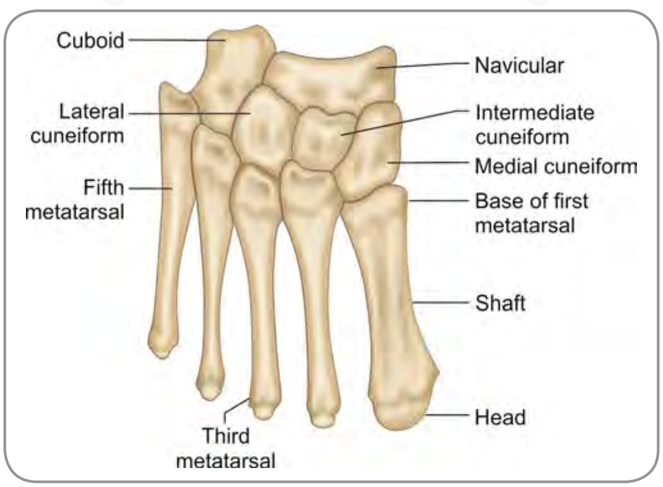


Fig. 22.51: Scheme to show the articulations of the metatarsal bones

  - Proximally with the cuboid bone,
  - Medially with the lateral cuneiform bone and with the base of the third metatarsal and
  - Laterally with the base of the fifth metatarsal bone
- The fifth metatarsal bone articulates proximally with the cuboid bone and medially with the fourth metatarsal bone.

PHALANGES OF FOOT

Other name: Ossa digitorum pedis

The phalanges (Greek.phalange=row of soldiers) of the foot are arranged on a pattern similar to that of the hand.There are three phalanges in each toe, i.e. proximal, middle and distal except the great toe which has only two phalanges, ***proximal*** and ***distal***. The phalanges of the great toe are well developed. The rest of them diminish in size from medial to lateral side of the foot. A proximal phalanx has a large base with a concave facet for articulation with the concerned metatarsal. The shaft is generally convex dorsally. The head is relatively wide and has a pulley-shaped articular surface. A middle phalanx is pulley-shaped on its head. A distal phalanx has only one articular facet at its proximal end. Its distal end is flattened.

Ossification of the Bones of Foot

- The calcaneus has one main centre of ossification that appears in the fifth foetal month; and a secondary centre (for a scale-like epiphysis that covers its posterior part) that appears in the 6th to 8th year Fusion occurs between 15 and 20 years.
- All other tarsal bones normally have one centre each that appear as follows:
  Talus—6th foetal month
  Cuboid—Just before or after birth
  Medial cuneiform—3rd or 4th year
  Intermediate cuneiform—3rd year
  Lateral cuneiform—1st year
  Navicular—2nd year
- Each metatarsal bone has a primary centre for the shaft appearing in the 9th or 10th foetal week.
  - The first metatarsal has a secondary centre for its base appearing in the 3rd year.
  - The other metatarsals have secondary centres for their heads (not bases) appearing in the 3rd or 4th year (Compare with metacarpal bones).
  - The secondary centres unite with the shafts between the 17th and 20th years.
- Each phalanx has a primary centre for the shaft (appearing between the 8th and 15th foetal weeks); and a secondary centre for the base (appearing between the 2nd and 8th years) which unites with the shaft by the 18th year.

Clinical Correlation

Congenital Deformities

- Congenital deformities are frequently seen in the region of the ankle and foot, and are of various types. The general term ***talipes*** is applied to them. In the most common variety of deformity, the foot shows marked plantar flexion (***equines***=like the foot of a horse), and inversion (varus=inward bend). Hence, this condition is called ***talipes equinovarus***. In layman's parlance, it is called ***club foot***. The condition may be unilateral or bilateral.
- The medial longitudinal arch of the foot may be poorly developed (***pes planus*** or ***flat foot***). A flat footed person will have difficulty in walking long distances, or in running.
- Conversely, the foot may be too highly arched (***pes cavus***). This condition is often associated with neurological disorders.

Fractures of the Bones of The Foot

- These are not common. Occasionally the calcaneus and, less commonly, the talus may be fractured. In a fracture of the neck of the talus, there may be avascular necrosis of the head. Calcaneal fractures are often caused when a person falls on the heel. The bone may break up into small pieces (comminuted fracture).
- Metatarsal bones and phalanges of the foot can be fractured by the dropping of a heavy object on the foot.
- The fifth metatarsal bone can be fractured through its base as a result of a twisting injury of the foot.
- Metatarsal bones can also be fractured by the stress of prolonged walking or running (***fatigue fracture, stress fracture or March fracture***).
- Metatarsal bones sometimes fracture when a dancer loses balance and the weight of the body falls on these bones.

General Arrangement of the Bones of Lower Extremity

The primary function of the lower limbs is to support the body during standing and locomotion. Weight bearing and transmission thus become important. Body weight, which is initially borne by the vertebral column, is transferred to the pelvis through the sacroiliac joints, and from the pelvis to the femora through the hip joints.

From the femora, the body weight has to be transferred to the ground through the distal parts of the limb. The erect bipedal posture of humans is the key deciding factor in the position adapted by the femora. The femora are set oblique and directed inferomedially. This setting causes the knees to remain adjacent to each other and get placed directly below the trunk. The centre of gravity therefore, falls within the base of the legs and the feet, thus making bipedal posture possible.

In the leg, the tibiae bear the body weight. The talus bone which is the key bone of the tarsus, is set into the mortice formed by the two malleoli and transmits weight both anteriorly and posteriorly. The bones of the foot are disposed in a such a way that both longitudinal and horizontal arches are produced. The arches help not only in stability but also facilitate walking, running and other locomotor activities

Multiple Choice Questions

1. One of the following details about acetabulum is false. Which is it?
   a. The artcular area is called the lunate surface
   b. The deficiency in its margin is the acetabular notch
   c. Superiorly it forms a lateral projection for weight transmission
   d Lunate surface is widest anteriorly
2. Linea terminalis of pelvis includes:
   a. arcuate line, pecten pubis and pubic crest
   b. pubic crest, pecten pubis and sacral promontory
   c. pubic crest, pecten pubis and superior ramus of pubis
   d. pecten pubis, arcuate line and sacral promontory
3. Which of these is incorrect?
   a. The lateral aspect of the lateral condyle of femur is more or less flat
   b. Adductor tubercle is present on the medial condyle of femur
   c. The intercondylar fossa has several vascular foramina
   d. The tibial articular surface covers only the inferior aspect of each condyle
4. Regarding ossification of femur, which is true?
   a. It is the second long bone in the body to start ossifying
   b. The secondary centre for its head appears immediately after the primary centre
   c. The neck ossifies from its own secondary centre
   d. The upper end of the bone is the growing end
5. One of the staements is false. Which is it?
   a. The trochlear articular surface on the talus is for articulation with tibia
   b. The anterior tuberosity of the calcaneum is an extension of the lateral process of calcaneal tuberosity
   c. The medial projecting aspect of the navicular bone is its tuberosity
   d. Intermediate cuneiform is the smallest of the cuneiform group

ANSWERS

1 d **2.** a **3.** d **4.** a **5.** b

Clinical Problem-solving

Case Study 1: Parts of two pelves were obtained during an archaeological excavation. The medical officer of the nearby village was at the site. The village headman commented that the two specimens probably belonged to a man and his wife. The medical officer, after taking a closer look at the specimens, refuted the statement and said that both were 'male'.

- Do you think it is possible for the medical officer to have decided that they were 'male' specimens? If so, how?
- Enumerate the sex differences found in the pubis bone.
- Why is the true pelvis broader and shallower in females?

Case Study 2: A 9-year-old boy, who had an accidental fall, complained of pain in his right leg. His x-ray confirmed that there was no fracture. His orthopaedician, after a thorough examination of his leg, asked the boy to perform various movements of foot and toes. The doctor also examined the boy's fibular region.

- Why was the doctor specifically checking his fibular region and various movements?
- Which nerve was he trying to check? And why?
- Though the fibula is not weight-bearing, what is its major role in the leg?

(For solutions see Appendix).

Chapter 23

Front and Medial Side of Thigh

Frequently Asked Questions

- Write in detail about the fascia lata and its specialisations.
- Write notes on: (a) Saphenous opening, (b) Iliotibial tract, (c) Femoral canal, (d) Femoral ring, (e) Sartorius.
- Discuss the adductor canal in detail.
- Write notes on: (a) Quadriceps femoris, (b) Adductor magnus, (c) Femoral sheath, (d) Profunda femoris artery
- Write in detail about femoral artery and its branches.
- Write briefly on: (a) Obturator nerve, (b) Perforating branches of profunda, (c) Tensor fasciae latae.

The thigh is that part of the lower limb which lies between the hip and the knee. It is otherwise called the ***regio femorae*** (Latin.Femore=thigh). The upper limit of the thigh on its anterior aspect is formed by the inguinal ligament. Hence, that part of the front of thigh immediately below the inguinal ligament is called the subinguinal region. Though the entire thigh is technically the femoral region (the thigh bone is femur and that region related to the femur is the femoral region), it is customary to label the front of thigh as the femoral region. The posterior aspect of thigh is usually called the hamstring region.

COMPARTMENTS AND REGIONS OF THIGH

The thigh is divided into anterior, medial and posterior compartments by the femur and two intermuscular septa. These septa are extensions of the deep fascia. The medial intermuscular septum passes from the deep fascia to the medial lip of the linea aspera. It separates the anterior and medial compartments and is thin. The lateral intermuscular septum passes from the deep fascia to the lateral lip of the linea aspera. It separates the anterior and posterior compartments and is strong and thick. The posterior intermuscular septum passes from the deep fascia to the medial lip of the linea aspera. It separates the medial and posterior compartments. Very often, the posterior septum is not a continuous structure but is found in numerous pieces.

Each of these compartments has its own blood and nerve supply.

However, if nerve supply and functionality are considered, the thigh, theoretically can be described to have four compartments. The anterior compartment has the flexors of hip and the extensors of knee and is supplied by the femoral nerve. The posterior compartment contains the extensors of hip and the flexors of knee and is supplied by the sciatic nerve. The medial compartment contains the adductors of hip and is supplied by the obturator nerve. The lateral compartment, if this theoretical description is true, should have the abductors of hip supplied by the superior gluteal nerve. In actual disposition, there are only three compartments. The lateral compartment is 'not found' because two of the three abductors (glutei medius and minimus) stop above the level of the greater trochanter and the third (tensor fasciae latae) is enclosed within the layers of the iliotibial tract. Therefore, the lateral compartment is essentially lost. The muscles of the other three compartments encircle the femur. The muscles of the anterior compartment almost completely surround the femur. Only a thin portion of the posterior aspect is left free for the attachment of the other muscles and the intermuscular septa. This thin portion forms the linea aspera.

Important Structures to be Noted in the Anterior Thigh

Before studying the details of the structures, further, it is important to know about and notice those structures which are found in the anterior thigh.

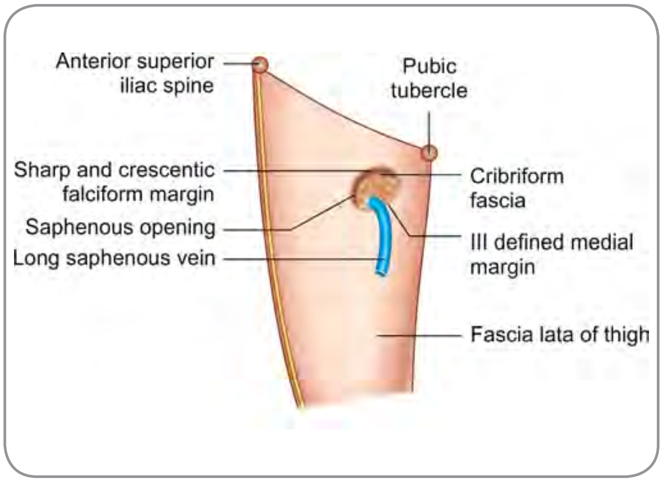


Fig. 23.1: Scheme to show position of saphenous opening and its falciform margin

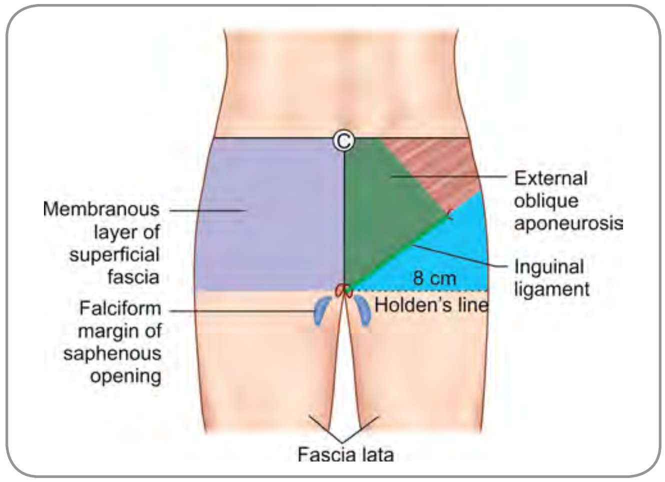


Fig. 23.2: Scheme to show Holden's line below the inguinal ligament

- At the upper end of the front of the thigh, i.e., at its junction with the anterior abdominal wall is the ***inguinal ligament***. The ligament is attached at its lateral end to the anterior superior iliac spine and at its medial end to the pubic tubercle. It actually is the folded lower edge of the aponeurosis of a muscle of the abdominal wall called the external oblique muscle. The ligament has a gentle downward convexity
- Near the medial end of the inguinal ligament is seen the ***spermatic cord***. It is seen to emerge through an aperture in the abdominal wall located just above the medial end of the inguinal ligament. This aperture is called the ***superficial inguinal ring***.
- A little below the medial end of the inguinal ligament is the ***saphenous opening*** (Fig. 23.1). This is an oval aperture in the deep fascia of the thigh. The superior, lateral and inferior margins of the opening are sharp and form what is called the ***falciform margin***.
- The saphenous opening is closed by a sheet of fascia which has many small holes in it. This is the ***cribriform fascia***.
- The saphenous vein can be seen curving around the lower margin of the saphenous opening, pierce the cribriform fascia and join the femoral vein.
- The cribriform fascia is also penetrated by three small branches of the femoral artery. These are the ***superficial circumflex iliac artery*** (laterally), the ***superficial epigastric artery*** (in the middle) and the ***superficial external pudendal artery*** (on the medial side).
- Veins accompanying these three arteries usually end in the terminal part of the saphenous vein before the latter pierces the cribriform fascia.

The skin is thick and tough over the buttock, the lateral aspect of the limb and the bearing points of the sole.

The superficial fascia of the lower limb is generally continuous with that of the rest of the body. However, in the upper part of the front of the thigh, it is different in that it consists of two layers. There is a superficial fatty layer and a deep membranous layer. Both these layers are continuous with similar layers of the anterior abdominal wall. The membranous layer is loosely attached to the deep fascia in the upper part. The membranous layer and the deep fascia fuse with each other along a horizontal line starting at the pubic tubercle and passing laterally for about 8 cm. This horizontal line is referred to as ***Holden's line*** (Fig. 23.2)

Clinical Correlation

- The importance of this line is as follows:
  - Sometimes the urethra may rupture in the perineum as a result of injury.
  - Urine may flow out of the ruptured urethra and enter the space deep to the membranous layer of superficial fascia. This is called ***extravasation*** of urine.
  - The fascia in the perineum is directly continuous (over the pubic symphysis) with the corresponding fascia over the abdominal wall. Therefore, the extravasated urine can pass upwards on to the abdominal wall. It can then pass laterally and flow across the inguinal ligament into the thigh.
  - However, the firm attachment of fascial layers along the Holden s line prevents this urine from descending lower into the thigh.
  - Holden's line is immediately distal to the inguinal ligament. The lateral extent of this line runs outward between the anterior superior iliac spine (inferiorly) and the greater trochanter (inferiorly) and serves as a marker to the capsule of the hip joint.

The deep fascia of the thigh, called the ***fascia lata*** (Latin.latus=broad and strong), deserves special mention and a detailed study. It is strong. It surrounds the internal structures like a sleeve. It can be imagined to be a cylinder and as a rule, has superior and inferior ring of attachments If traced from pubic tubercle, the superior ring of attachment serially continues along the inguinal ligament,

anterior superior iliac spine, iliac crest, sacrotuberous ligament, ischial tuberosity, conjoined ischiopubic ramus, pubic symphysis, pubic crest and superior pubic ramus. It can thus be seen that the superior attachment is not a simple 'ring' in that the starting point of the ring and the ending point are not one and the same. There is an overlap in the attachment. Instead of 'ending' at the pubic tubercle (where it 'starts'), a lateral extension passes posterior to the femoral sheath and is attached along the superior pubic ramus. Thus, there are two strata of the fascia lata in this part. A little below, the sleeve regains its cylindrical form The inferior ring of attachment is along the patella, the lateral femoral and tibial condyles, the capsule of the knee joint and the medial femoral and tibial condyles. The fascia lata along its inferior ring of attachment becomes continuous with the deep fascia of the leg.

Since the fascia lata is attached to the iliac crest and the sacrotuberous ligament, it covers the gluteal muscles too. That part of the deep fascia which is over the gluteal muscles is sometimes called the ***gluteal fascia*** and the name fascia lata is usually restricted to the deep fascia of the thigh proper. When the fascia descends over the gluteus medius from the iliac crest, it splits into two as it reaches the upper border of gluteus maximus. One of the layers passes superficial to the muscle and the other deep to the muscle to reunite at its lower border.

Specialisations of fascia lata: The fascia lata exhibits special features of structural and functional importance.

- ***Iliotibial tract (Fig. 23.3):*** Along the lateral margin of the thigh, the fascia lata is thickened and forms a strong band passing from the anterior part of the iliac crest to the upper end of the tibia. This band is, therefore, called the ***iliotibial tract***. At its upper end, the tract splits into two layers to enclose a muscle called the ***tensor fasciae latae***. On its posterior aspect, it also receives most of the fibres of gluteus maximus. Of the two layers, the superficial one ascends lateral to the tensor fasciae latae muscle and gets attached to the outer lip of the iliac crest. The deeper layer passes deep to the tensor fasciae latae and blends with the lateral part of the capsule of the hip joint. Both the superficial and deep layers are composed of circularly disposed fibres. The tensor fascia latae and the gluteus maximus muscles contribute to a set of vertical fibres which descend between the two sets of circular fibres and form the bulk of the tract. The area of attachment of the iliotibial tract to the tibia forms a prominent triangular impression on the anterolateral aspect of the lateral tibial condyle bone. This s called the Gerdy's tubercle. An aponeurotic expansion from the vastus lateralis merges with the iliotibial tract here. The tract stands out as a prominent ridge on the anterolateral aspect of the knee when the leg is extended.

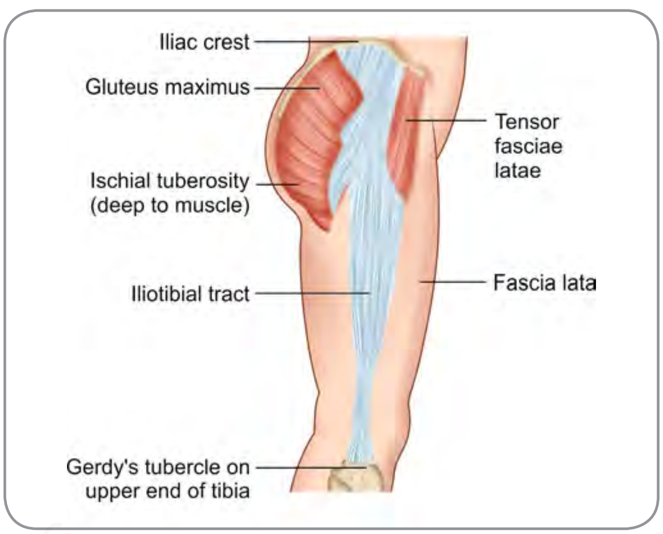


Fig 23.3: Scheme to show illotibial tract on lateral side of thigh and gluteal region

- ***Saphenous opening:*** An opening in a sheet or fascia is usually a deficit in the structure. It is not so with the saphenous opening. The opening is formed not because a small portion of the fascia is lacking but because the two strata of the fascia have overlapped. It is to be imagined like the gap created when the right and left flaps of the front of a coat are overlapped. As already seen, the fascia lata has two strata—1. the superficial and 2. the deep–in the upper part of the thigh The superficial stratum is attached to the pubic tubercle, the inguinal ligament and the anterior superior iliac spine. The lower rim of this superficial stratum is curved and concave. This rim forms the superior, lateral and inferior curves of the saphenous opening and is called the ***falciform margin***. The superior and lateral curves are sharp. The superior and inferior curves are also called the ***superior*** and ***inferior cornua***. The lower rim of the deep stratum continues from the inferior cornu and extends superolaterally covering the pectineus, adductor longus and gracilis muscles. The deep stratum gets attached to the pubic tubercle and the pecten pubis of the superior pubic ramus. Since the deep stratum stretches behind the femoral sheath, there is no clear cut medial margin for the saphenous opening.

The saphenous opening is below and lateral to the medial part of the inguinal ligament; the centre of the opening is about 3 cm inferior and lateral to the pubic tubercle. The opening is closed by the cribriform fascia which is a part of the superficial fascia. The cribriform fascia is attached to the falciform margin on the lateral aspect; on the medial aspect it merges imperceptibly with the deep stratum. The great saphenous vein pierces the cribriform fascia and passes through the saphenous opening to join the femoral vein. Other smaller

unnamed veins may also pass through this opening or through adjacent smaller subsidiary openings. The superficial stratum of the fascia lata is anterior to the femoral sheath and merges with the anterior layer of the sheath. The deep stratum is posterior to the femoral sheath but separated from it by loose connective tissue.

Added Information

- The saphenous vein ascends to the level of the thigh and a saphenous opening is present only in the human.
- The other names for the saphenous opening are saphenous hiatus and fossa ovalis.
- The great saphenous vein actually hooks over the inferior cornu; this 'hooking' and the consequent 'drag' are supposed to the reasons for the opening being oval-shaped in the human.

ANTERIOR AND MEDIAL COMPARTMENTS OF THIGH

The ***anterior compartment*** of the thigh, otherwise called the ***flexor compartment*** or the ***femoral compartment***, lies in front of the medial and the lateral intermuscular septa. The compartment actually encircles most of the shaft of the femur and consists of bulky muscles. The ***medial compartment***, otherwise called the ***adductor compartment*** or the ***obturator compartment***, lies behind the medial intermuscular septum and in front of the posterior intermuscular septum

Though the two compartments are described separately, the muscles of both the compartments are seen together on removal of deep fascia in the front of thigh. Their separation is not well defined because the medial intermuscular septum is thin and weak. Running diagonally across the thigh from the lateral to the medial aspect is the thin and long muscle called the ***sartorius***. Running downwards along the lateral margin of the upper part of the thigh are the ***tensor fasciae latae*** and the ***iliotibial tract.*** Parts of a large muscle called the ***quadriceps femoris*** are seen between the sartorius and the tensor fasciae latae. That part of the quadriceps running more or less vertically down the centre of the thigh is the ***rectus femoris***. To the lateral side of the rectus femoris is the ***vastus lateralis;*** to the medial side of the rectus femoris is the ***vastus medialis***. Deep to rectus femoris, vastus medialis and vastus lateralis is the vastus intermedius The rectus and the three vasti together form the quadriceps.

Two muscles are seen medial to the upper part of the sartorius. These are the ***iliacus*** laterally and the ***psoas major*** medially. The area medial to the sartorius and below the level of the psoas major is occupied by a number of muscle belonging to the medial compartment of the thigh. From above downwards, these are the a. ***pectineus,*** b. ***adductor longus,*** c. ***adductor magnus*** and d. ***gracilis***.

Deep to the adductor longus is another muscle called the ***adductor brevis***.

Disposition of the various muscles leads to the formation of a muscular triangle called the femoral triangle in the upper part of anterior thigh. It cannot be restricted to the anterior compartment because its medial boundary is formed by a muscle of the medial compartment, namely the adductor longus which also forms part of the floor of the triangle.

Femoral Triangle (Fig. 23.4A)

The femoral triangle is the slightly depressed region on the front of thigh, inferior to the inguinal ligament and medial to the sartorius. The region is of importance, as it contains several vessels and nerves. The triangle has a superiorly placed base and an inferiorly placed apex.

The ***boundaries*** of the triangle are as follows:

- The superior ***boundary*** or ***base*** is the inguinal ligament;
- The ***lateral boundary*** is the medial margin of sartorius;
- The ***medial boundary*** is the medial margin of adductor longus;
- The apex is where the medial and the lateral borders meet.

The ***floor*** of the triangle is formed (from lateral to medial side) by the iliacus, the psoas major, the pectineus and the adductor longus muscles. The ***roof*** is formed by the fasciae over the region and the superficial structures within them. These include the saphenous opening, the cribriform fascia, the terminal part of the saphenous vein and the superficial inguinal lymph nodes.

The contents of the triangle are (Fig. 23.4B):

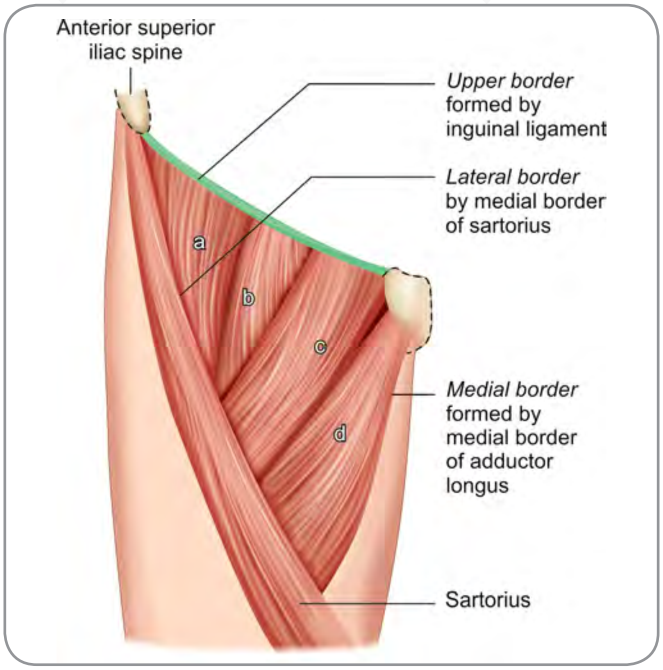


Fig. 23.4A: Scheme to show boundaries and floor of the femoral triangle. The floor muscles of the triangle are shown a, iliacus; b psoas major; c, pectineus; d, adductor longus

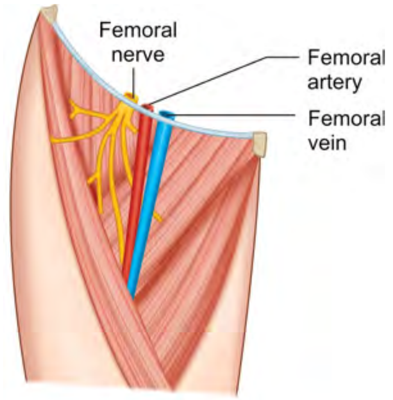


Fig. 23.4B: The main contents of femoral triangle

- The ***femoral artery*** which runs down the middle of the triangle, from midbase to the apex and some of its branches;
- The ***femoral vein*** which has a close but twisted relationship to the artery;
- The ***femoral nerve*** which is a short distance lateral to the artery and some of its branches;
- The deep inguinal lymph nodes;
- The profunda femoris and the circumflex vessels.

Branches and tributaries of the vessels and nerve in the femoral triangle:

- As the femoral artery passes through the femoral triangle, it gives out several branches to adjacent structures.
  - Three branches are given off just below the inguinal ligament. These are the (a) ***superficial circumflex iliac artery***, (b) ***superficial epigastric artery*** and (c) ***superficial external pudendal artery***. They pass through the cribriform fascia to become superficial.
  - A short distance below the inguinal ligament, two other branches are given off: a. the ***deep external pudendal artery*** that arises from the medial side of the femoral artery and runs medially over the floor of the triangle; b. the ***profunda femoris artery*** that arises from the posterolateral aspect of the femoral artery and runs downwards lateral to the femoral artery; the medial and lateral circumflex femoral branches of the profunda femoris artery are also given out in the femoral triangle.
- The upper end of the femoral vein lies medial to the femoral artery However, at the apex of the femoral triangle, the vein lies posterior to the artery. The vein, therefore, appears to be twisted around the artery. The great saphenous vein joins the femoral vein at the saphenous opening. Other tributaries of the femoral vein correspond to branches of the femoral artery.
- After a short course of just about an inch in the femoral triangle, the femoral nerve divides into anterior and posterior divisions, each of which divides into a number of branches. The anterior division gives off a muscular branch to the sartorius muscle, the ***medial*** and ***intermediate cutaneous nerves of the thigh***. The posterior division gives off muscular branches to the rectus femoris, vastus lateralis, vastus intermedius and vastus medialis and a large sensory branch called the ***saphenous nerve.***

Other structures found in the femoral triangle are as follows:

- Medial to the femoral nerve, the ***nerve to pectineus*** is seen. This nerve actually arises from the femoral nerve within the pelvis and enters the thigh by passing deep to the inguinal ligament. It passes medially deep to the femoral sheath (and so, the artery) to reach the pectineus.
- The ***femoral branch of the genitofemoral nerve*** can be seen running downwards anterior to the femoral artery. This nerve is a branch of the genitofemoral nerve, a nerve of the lumbar plexus. Given out as one of the two branches of the main nerve just above the inguinal ligament, it passes deep to the inguinal ligament and enters the femoral sheath lateral to the femoral artery. It then pierces the anterior layer of the femoral sheath and fascia lata to reach the cutaneous plane. It supplies the skin over the upper part of the femoral triangle.
- The ***lateral cutaneous nerve of the thigh*** is seen near the lateral angle of the femoral triangle.

Femoral Sheath (Fig. 23.5)

The femoral vessels are in the femoral sheath as they pass through the femoral triangle. The femoral sheath is a funnel-shaped fibroareolar structure that wraps around the femoral vessels in the upper part of the thigh.

Formation: It is essential to know a few details about the abdominal walls before we proceed to study the femoral sheath. The posterior abdominal wall has the iliacus and psoas major muscles on its internal aspect. They are covered by a fascia called the iliopsoas fascia (or simply, the iliac fascia) on their anterior aspects. The iliopsoas passes behind the inguinal ligament into the thigh from the abdomen. On the anterior aspect, the innermost muscle of the anterior abdominal wall is the transverses abdominis; this muscle is lined by the transversalis fascia. The lower limbs attach to the trunk of the body on its lower aspect. It is naturally expected that at the lower aspect of the trunk, the anterior and posterior walls would come towards each other and join to close off the body cavity. In such a case, the transversalis fascia from the anterior aspect and the iliac fascia from the posterior aspect would also join together and seal the cavity. However, this is not so in the area where the lower limb continues from the trunk. The femoral vessels pass into the thigh from the abdomen; as

they emerge so, a sleeve of fibroareolar tissue is dragged along. The anterior part of this sleeve (forming the anterior wall) is contributed to by the transversalis fascia and the posterior part (forming the posterior wall) by the iliacus fascia. A little amount of extraperitoneal connective tissue also merges with these fasciae.

Shape and parts: The femoral sheath is funnel-shaped. Its medial portion lies behind the saphenous opening and the lateral portion behind the fascia lata. The ***superior*** or ***proximal end*** of the sheath is wider and open to the abdominal cavity. The ***inferior*** or ***distal end*** is narrower and merges with the perivascular connective tissue about 3 to 4 cm distal to the inguinal ligament. The ***lateral wall*** is more or less vertical. It is pierced by the femoral branch of the genitofemoral nerve. The ***medial wall*** slopes laterally. It is pierced by the great saphenous vein. The anterior and posterior walls are interconnected by two partitions, thus creating ***three compartments*** (Fig. 23.5). The ***lateral most compartment*** contains the femoral artery and the ***middle compartment*** contains the femoral vein. The ***medial most compartment***, also the smallest, is called the ***femoral canal*** It is occupied by a few lymphatic vessels and a lymph node (the ***lymph node of Cloquet*** or ***lacunar lymph node***). The lateral wall of the femoral canal is vertical and the medial wall is sloping. The presence of this canal permits distension of the femoral vein.

Femoral ring: The proximal end of the femoral canal is called the mouth of the femoral canal or the femoral ring. This is the area of connection between the abdominal cavity and the femoral canal. The ring is bounded anteriorly by the inguinal ligament, medially by the crescentic edge of the lacunar ligament, posteriorly by the pectineus muscle and its fascia and laterally by the femoral vein. The ring is larger in women than in men. Greater width of the pelvis and smaller size of the femoral vessels are the two reasons for the ring to be larger in women. Close to the anterior and anterolateral boundaries of the ring are the spermatic cord (or the round ligament) and the inferior epigastric vessels respectively. The ring is closed in life by a plate of extraperitoneal connective tissue; this plate is called the femoral septum. The femoral septum may be traversed by a few lymphatics.

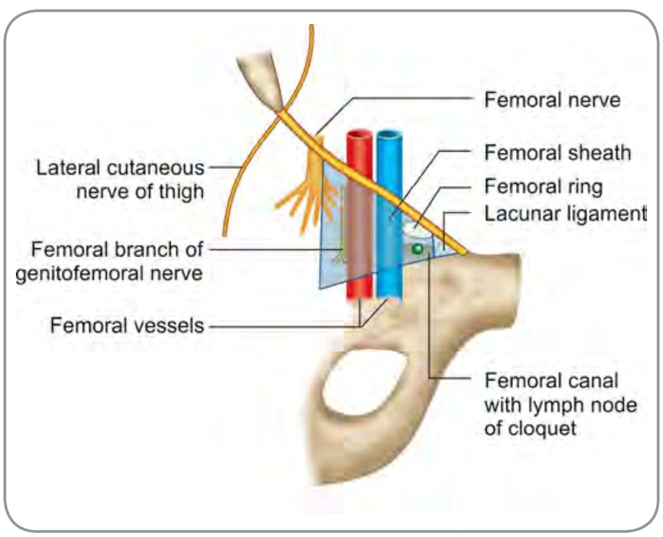


Fig 23.5: Femoral sheath showing its compartments with their contents (Note that femoral nerve is outside the femoral sheath)

Added Information

- The femoral triangle is otherwise called the triangle of Scarpa.
- The apex of the triangle lies approximately 4 inches inferior to the inguinal ligament.
- The dominant structure within the frame of the femoral triangle is the femoral artery. It cuts through the triangle from the midinguinal point to the apex.
- The artery runs along an internervous boundary—the boundary line that separates the territories of two motor nerves. The muscles of the medial part of the triangle are supplied by the obturator nerve and those of the lateral part by the femoral nerve.
- The profunda femoris artery arises from the femoral artery usually 2 to 5 cm below the inguinal ligament. Very rarely, it arises at the level of the inguinal ligament. In the case of the latter, two major arteries enter the lower limb.
- The femoral vein is posterior to the femoral artery at the level of the apex of the triangle. The profunda vessels also have a similar elation. Tough areolar tissue surrounds all the four vessels and all keep them united to one another
- The great saphenous vein is the last tributary to join the femoral vein.
- The femoral nerve enters the thigh lateral to the artery but outside the fascia iliaca. Therefore, the nerve is not enclosed in the femoral sheath.
- The relationship of the femoral vessels and the nerve to the hip joint are important. The artery is separated from the joint by the firm tendon of psoas major. The nerve is separated by the fleshy iliacus. The vein is separated by the thin pectineus.
- The femoral sheath permits the femoral vessels to glide smoothly deep to the inguinal ligament during movements of the hip joint.
- The inguinal ligament acts like a flexor retinaculum of the hip. The structures which are in front of the hip joint are likely to bowstring during flexion; this is prevented by the inguinal ligament which retains the structures in position.
- ***Retroinguinal space:*** As the inguinal ligament bridges the gap between the pubic tubercle and the ante ior superior iliac spine, a passageway between the abdominal cavity and the thigh is created. This passageway is called the retroinguinal space. This space is divided into two compartments by a fascial partition called the iliopectineal arch. The iliopectineal arch is a thickening of the medial portion of the iliacus fascia and runs from the deep aspect of inguinal ligament to the iliopubic eminence The compartment lateral to the iliopectineal arch is muscular; the iliopsoas muscle and the femoral nerve pass through this compartment. The compartment medial is vascular; the femoral vessels pass through it enclosed in the femoral sheath.

Clinical Correlation

Femoral hernia: The femoral canal is a weak area resulting in the occurrence of femoral hernia. Abdominal viscera (usually a coil of small intestine) can p otrude through the femoral ring into the femoral canal. As the intraabdominal pressure increases due to some reason, more and more of the length of the intestine descends into the femoral canal. A small femoral hernia appears as a rounded mass in the femoral triangle inferolateral to the pubic tubercle. When the hernia becomes larger in size, it en arges beyond the size of the femoral canal and passes through the saphenous opening (a passage easily available at this level) to reach the subcutaneous tissue. If the hernia increases still further in size, it extends towards the anterior superior iliac spine. In such a case the swelling produced by the hernia appears like a 'retort with a globular portion at the saphenous opening and a linear extension towards the anterior superior iliac spine.

Femoral herniae are commoner in women due to a wider femoral ring. Strangulation of femoral herniae are also commoner than that of other hernia; the boundaries of the femoral ring are rigid and the medial margin (concave margin of the lacunar ligament) is particularly sharp. This sharpness can cut through the tissue or impede the blood vessels.

While repairing the femoral hernia or while releasing a strangulated hernia, it may be necessary to widen the neck of the hernial sac. The neck lies at the femoral ring. On the lateral aspect of the ring is the femoral artery; trying to meddle in that direction may cause extensive bleeding and hence, should be avoided. The anterior and posterior aspects have firm structures in the form of the inguinal ligament and the superior pubic ramus respectively. Widening is possible only by cutting through the sharp concave border of the lacunar ligament. A 'normal' pubic branch of the obturator artery is well away from the lacunar ligament and is not endangered. Sometimes this branch is replaced by a pubic branch of the internal epigastric artery (called the ***replaced obturator artery***) or supplemented by the same (the pubic branch of the internal epigastric is then called an ***accessory obturator artery***); even then, most often, these arteries are away from the lacunar ligament. Rarely, either the replaced or the accessory obturator artery passes over the concave border of the lacunar ligament (named the ***aberrant obturator artery*** in such a case). This artery may inadvertently be cut during hernial repair and cause extensive bleeding.

MUSCLES OF THE ANTERIOR COMPARTMENT OF THIGH

The anterior compartment is a 'true' osseofascial compartment with bone and fasciae forming its boundaries. The muscles of this compartment (anterior thigh muscles) act as extensors of the hip and flexors of the knee. However, the compartment is called the extensor compartment, taking the action on the hip into consideration. The muscles are:

- Psoas major (Fig. 23.6)
- Psoas minor (Fig. 23.6)
- Iliacus (Fig. 23.6)
- Tensor fasciae latae
- Sartorius
- Rectus femoris
- Vasti – vastus medialis, vastus intermedius and vastus lateralis
- Articularis genu

The psoas and iliacus muscles are often considered as abdominal muscles since the major bulk of them is within the abdomen and only the tendons of distal attachment reach the lower limb. The psoas minor is not always present. If present, the muscle lies within the abdomen but is closely associated w th the psoas major.

The rectus femoris and the three vasti together form the quadriceps femoris; they act on the knee joint through a common tendon and hence are considered as one muscle. Articularis genu is a part of the vastus intermedius Of the 'true' muscles of the anterior compartment, tensor fasciae latae, sartorius and rectus femoris act on both the hip and the knee. The three vasti (and so, the articularis genu) act only on the knee.

Adductor longus and pectineus, which are muscles of the medial compartment are sometimes grouped in the anterior compartment because of their presence in the front of thigh. Tensor fasciae latae is classified as a gluteal muscle by the clinicians

Additional Notes on Iliopsoas

The iliopsoas is the chief flexor of the thigh and acts over a long range. It is the only muscle attached to the vertebral column, pelvis and femur. The muscle is active during walking. When the thigh is fixed, bilateral contraction of iliopsoas causes flexion of hip. Iliopsoas is actively involved in climbing downstairs and in maintenance of normal posture.

Additional Notes on Sartorius

It is the longest muscle in the body, being in the shape of a narrow strap. It crosses the thigh obliquely from the lateral to the medial side. It acts on both the hip and the knee causing flexion at both joints. The muscle is particularly active when both these actions are combined. The name of the muscle (Latin.Sartus= patching or repair; sartor=tailor) is derived from its efficacy in causing flexion at hip and knee simultaneously which are required for a tailor in professing the occupation. The muscle also causes abduction and lateral rotation of the thigh. Though the muscle does not a major role to play in walking on even ground, it is very active while climbing stairs. At its insertion it forms part of the 'pes anserinus'. A sheet of dense fibrous tissue passes from the insertion of sartorius to the deep fascia of the leg; since this sheet passes superficial to the insertions of gracilis and semitendinosus, it has to be split

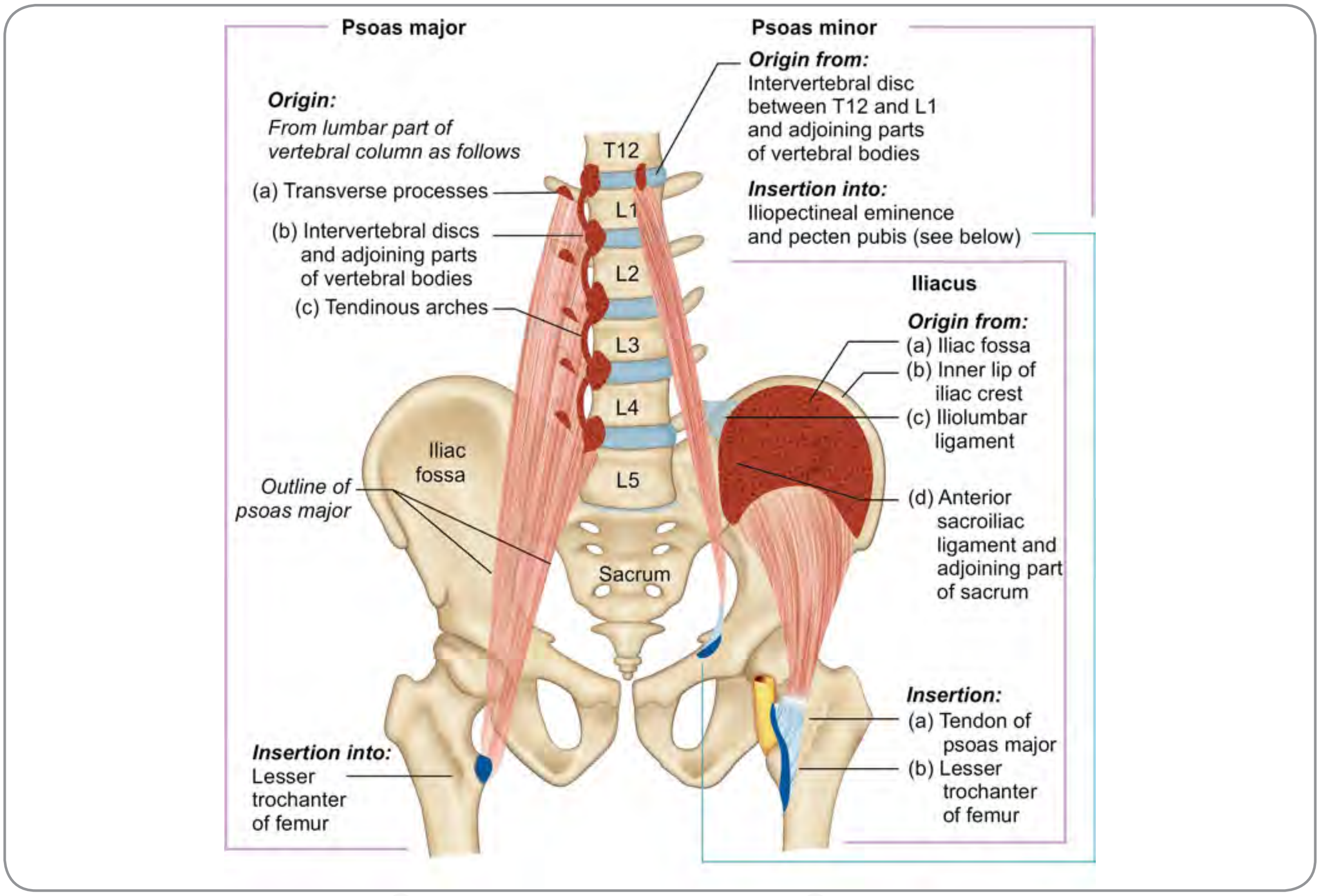


Fig. 23 6: Scheme to show attachments of psoas major, psoas minor and iliacus

Table 23.1: Quadriceps femoris and its parts (Fig. 23.7)

<table>
<tr><th colspan="3">Attachments of individual parts</th><th>Ultimate insertion of quadriceps femoris</th></tr>
<tr><th>Part</th><th>Origin</th><th>Insertion</th><td rowspan="3">• All the four parts of the muscle are inserted into the patella
• The patella transmits their pull to the ligamentum patellae
• The lower end of the ligamentum patellae is attached to the tibial tuberosity (smooth upper part)
• Thus, the quadriceps femoris is ultimately inserted into the tibia</td></tr>
<tr><td>Rectus femoris</td><td>Tendinous origin from hip bone by two heads:
• Straight head: From anterior inferior iliac spine
• Reflected head: From ilium just above acetabulum</td><td>Upper border of patella</td></tr>
<tr><td>Vastus medialis</td><td>From following parts of shaft of femur:
• Intertrochanteric line, lower part
• Spiral line
• Medial lip of linea aspera
• Medial supracondylar line</td><td>• Medial border of patella
• Through medial patellar retinaculum into medial condyle of tibia</td></tr>
<tr><td>Vastus intermedius</td><td>From shaft of femur:
• Anterior surface
• Lateral surface</td><td>Upper border of patella (deep to rectus femoris)</td><td>Nerve supply and actions of quadriceps femoris

• Nerve supply: Femoral nerve (L2, L3, L4)
• Actions of quadriceps femoris:
– The muscle straightens the lower extremity at the knee (as in standing up from a sitting position)
– When sitting down, the muscle relaxes gradually and ensures proper control
– The rectus femoris can flex the thigh. It can rotate the pelvis on the head of the femur
– The vastus medialis prevents lateral displacement of the patella</td></tr>
<tr><td>Vastus lateralis</td><td>From following parts of femur:
• Upper end of intertrochanteric line
• Anterior border of greater trochanter
• Lower border of greater trochanter
• Lateral margin of gluteal tuberosity
• Lateral lip of linea aspera</td><td>• Lateral border of patella
• Through lateral patellar retinaculum into lateral condyle of tibia</td><td></td></tr>
</table>

Table 23.2: Tensor fasciae latae and sartorius		
Muscle	**Tensor fasciae latae (Fig 23.8)**	**Sartorius (Fig. 23.9)**
Origin	• Anterior part of outer lip of iliac crest • Outer aspect of anterior superior iliac spine	• Anterior superior iliac spine • Small area below the spine
Insertion	Upper end of iliotibial tract. Through this tract, it pulls on the lateral condyle of the tibia (triangular area on front of condyle)	Upper end of tibia (on a vertical line on the upper part of medial surface). Insertion is anterior to that of the gracilis and of semitendinosus
Nerve supply	Superior gluteal nerve (L4, L5, S1)	Femoral nerve (L2, L3)
Action	• Helps to maintain erect posture. It stablises the pelvis on head of femur, and the femur on the tibia • Helps to extend the leg • Helps in medial rotation of thigh • May abduct the thigh	Helps in: • Flexion of leg (at knee joint) • Flexion of thigh (at hip joint) • Abduction of thigh • Lateral rotation of thigh
Note	Length of the muscle is variable	• The medial border of the upper part of the sartorius forms the lateral boundary of the femoral triangle • Forms roof of adductor canal (in middle one-third of thigh)

open to expose the tendons of those muscles (required during certain surgical procedures).

Additional Notes on the Vasti

- Vastus medialis has a long origin. The muscle fibres from the upper part of the origin descend downwards and forwards at an angle of about 15° to the long axis of the femur. The lowest fibres which take origin from the tendon of adductor magnus and insert into the medial border of patella are much more horizontal. They are considered to be a separate part of the muscle. This part is referred to as the vastus medialis obliquus and seems to play an important role in the stability of the patellofemoral joint. It can be as a prominent bulge medial to the patella in the living individual. Vastus medialis forms the lateral wall of the adductor canal. It is otherwise called the ***vastus internus*** or ***medial great muscle*** (Latin.Vasta=great).
- Vastus lateralis is the largest component of the quadriceps. It is otherwise called the ***vastus externus*** or the ***lateral great muscle***.

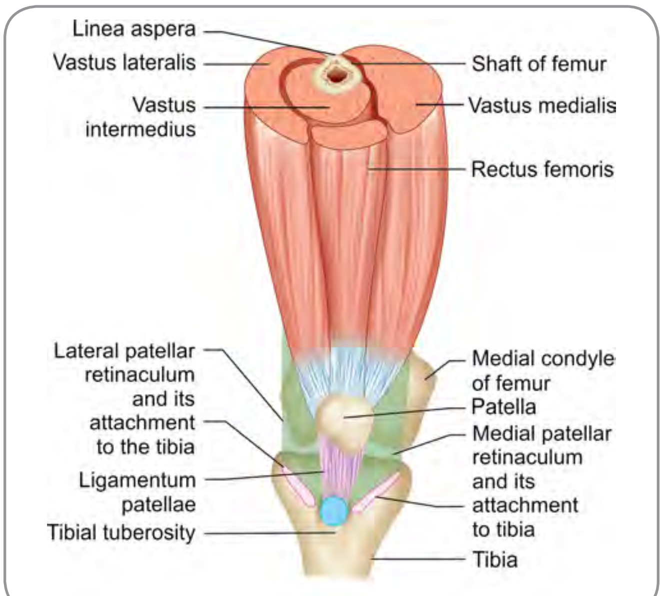


Fig. 23.7: Quadriceps femoris and its parts

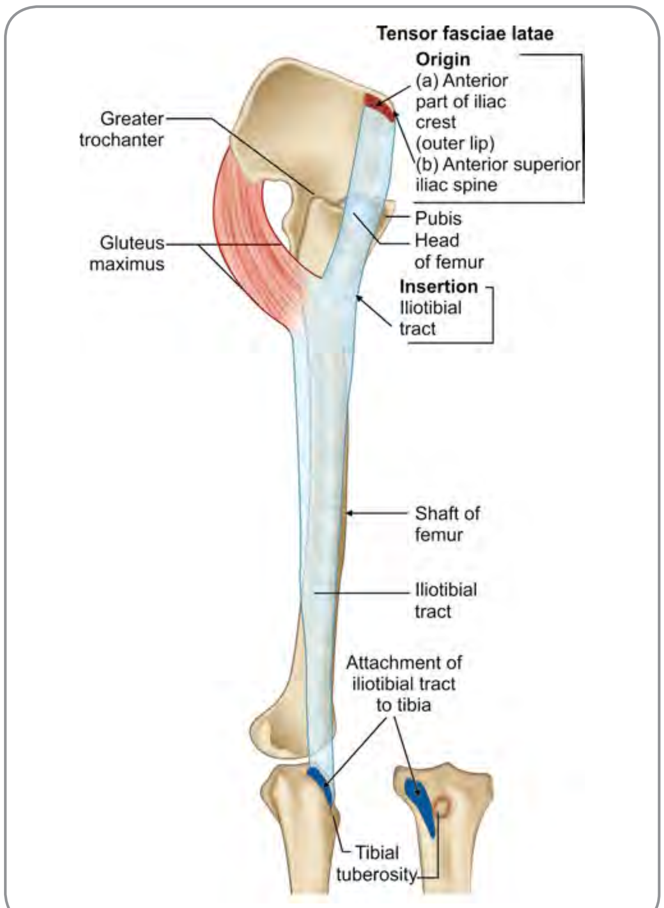


Fig. 23.8: Scheme to show the attachments of the tensor fasciae latae and iliot bial tract

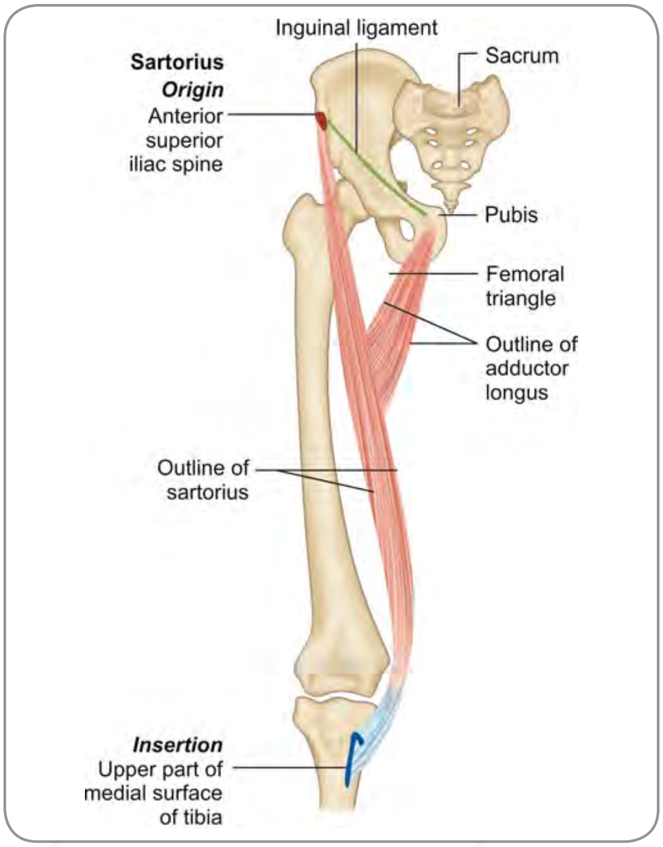


Fig. 23.9: Scheme to show the attachments of the sartorius

- Vastus intermedius is very closely approximated to the shaft of femur and is almost completely covered by the other parts of the quadriceps An arterial anastomotic network occurs deep to this muscle. Apart from supplying the articularis genu and the suprapatellar bursa, this network also serves as a collateral pathway when the femoral artery is blocked. The vastus intermedius is otherwise called the ***intermediate great muscle***.

Patellar ligament and retinacula: All the four parts of the quadriceps unite in the distal thigh to form a single and strong quadriceps tendon. The tendon attaches to the patella. The patellar ligament or the ligamentum patellae runs from the patella to the tibial tuberosity. The ligamentum patellae is actually a continuation of the quadriceps tendon and the patella is embedded in it as a sesamoid bone. The vastus medialis and lateralis also attach to the patella through the patellar retinacula. The retinacula, which are extensions of the aponeuroses of the muscles, reinforce the capsule of the knee joint and retain the patella over the trochlear surface of the femur.

Actions of quadriceps femoris: As already noted, the muscle extends the knee. However, in standing (where the knee is already extended), the muscle plays no role. The muscle is active while rising from sitting, climbing stairs and walking uphill. Since the rectus is attached to the hip bone proximally, it pulls the patella along the mechanical axis of the lower limb, which is the line connecting the centres of the hip, knee and ankle joints. The three vasti have no attachment to the hip bone and originate only from the femoral shaft. They pull the patella along the anatomical axis of the femur, which is the intramedullary long axis of the bone. The anatomical axis is at an angle of 5 to 7° to the mechanical axis. Pull by the vasti tends to displace the patella laterally. A deep femoral trochlear groove and a well projected lateral femoral condyle tend to counter this lateral pull, but are insufficient. The major counter factor is the action of the vastus medialis. The attachment of the vastus medialis tendon to the medial border of the patella extends to a lower level when compared to the attachment of the vastus lateralis tendon to the lateral border of the patella When the vasti contract, the total force exerted by the vastus medialis is more than that of the vastus lateralis and the patella is pulled medially. It is the vastus medialis obliquus component that plays a major role; the horizontal disposition of its fibres contribute largely.

Blood supply of quadriceps: A large branch of the lateral circumflex femoral artery supplies branches to the rectus and the vasti except the vastus medialis. This branch, which may sometimes arise from the profunda femoris directly, is called the 'artery of the quadriceps'. While the rectus receives branches only from the artery of the quadriceps, vastus lateralis and intermedius receive additional reinforcements from the lateral circumflex femoral and the profunda femoris arteries respectively. Vastus medialis receives branches directly from the femoral artery with minor reinforcements from the profunda femoris. The blood supply of all the components of the quadriceps gain importance due to the possibility of raising various fasciocutaneous and musculocutaneous flaps in cosmetic surgery procedures.

Additional Notes on Articularis Genu

Though it is customary to describe the articularis genu as a part of vastus intermedius, the former is very often a separate and distinct muscle. It arises as a number of muscular slips from the lower part of the anterior surface of the femoral shaft; all the slips merge together and are inserted into the convex fundus of the suprapatellar bursa. During extension of knee, the suprapatellar bursa may be caught between the femur and the tibia. Articularis genu averts this by pulling and retracting the bursa upward. Its nerve supply is by the femoral nerve L2, L3 and L4.

Additional Notes on Tensor Fasciae Latae

The role played by this muscle in maintaining the erect posture is of importance. By acting through the iliotibial

tract, it reduces energy expenditure that would be normally spent if it were only muscular activity. When an individual is standing, tensor fasciae latae, by acting from below and by acting through the iliotibial tract, steadies the pelvis on the femoral heads and steadies the femoral condyles on the tibial condyles. Tensor fasciae latae is a weak extensor during the last fifteen degrees of knee extension and a weak flexor beyond fifteen degrees of flexion. A large ascending branch of the lateral circumflex femoral artery supplies most of the muscle except for the most superior part which is supplied by branches from the superior gluteal artery. The branch from the lateral circumflex femoral artery is important in that it is the pedicle of the tensor fasciae latae musculocutaneous flap.

Clinical Correlation

- ***Testing of tensor fasciae latae:*** The thigh is flexed against gravity. The knee is simultaneously extended. A depression will then be found inferior to the anterior superior iliac spine. The lateral boundary of this depression is the tensor fasciae latae.
- ***Testing of the quadriceps femoris:*** The individual is on supine position; hip joint is flexed. The knee is then extended against resistance.
- The rectus femoris sustains injuries during kicking and hence called the 'kicking muscle'.
- ***Hip pointer:*** This term refers to avulsion fractures of the bony attachments of sartorius or rectus to the anterior superior iliac spine and anterior inferior iliac spine respectively.
- ***Charley horse:*** This term refers to ischaemia or contusion of an individual anterior thigh muscle. The common cause is a direct trauma to the muscle which results in tearing of the muscular fibres, rupture of blood vessels and formation of haematoma. Pain and muscle stiffness are the symptoms.
- Pain deep to the patella can occur in persons doing a lot of running (e.g., long distance runners).
- Arthritis of knee results in weakness of the vastus medialis and lateralis which in turn causes knee joint instability and abnormal patellar movement.
- Over straining of the knee can occur in running sports or long distance running activities. Quadriceps suffers imbalance and leads to pain around and deep to patella. Direct blow to the patella can also cause a similar situation. All these conditions are together referred to as 'Chondromalacia patellae' or 'Runner's knee'.
- ***Psoas abscess:*** Tuberculosis of the vertebral column can result in a psoas abscess. Pus tracks through the psoas muscle and its fascia to the inguinal and thigh regions. Any soft swelling or oedema in the proximal thigh should immediately raise suspicion about a psoas abscess.
- When a person is sitting with the legs hanging free, striking the ligamentum patellae with a rubber hammer causes reflex extension of the knee. This is the ***knee jerk*** or ***patellar tendon reflex***. The reflex tests for the integrity of the femoral nerve and the L2 to L4 spinal segments. Any condition that causes paralysis of the quadriceps femoris (e g., injury to the femoral nerve) abolishes the reflex. The reflex is exaggerated in upper motor neuron paralysis (e.g., hemiplegia).

contd...

Clinical Correlation *contd...*

- There are bursae in relation to the patella (prepatellar, infrapatellar and suprapatellar bursae). The subcutaneous prepatellar bursa can get inflamed (bursitis) in persons like the housemaids and floor workers who support their weight on the knees for long periods. The soft swelling is anterior to the patella. Compressive forces or friction between the skin and the patella also cause this condition which is called ***housemaid's knee***. The subcutaneous infrapatellar bursa is inflamed when there is friction between the skin and the tibial tuberosity and the swelling is anterior to the upper end of tibia. The condition is called ***clergyman's knee***. The deep infrapatellar bursa is between the ligamentum patellae and the tibial tuberosity. Overuse of the ligamentum patellae or the quadriceps leads to friction between the tendon and the tibia resulting in deep infrapatellar bursitis. The swelling is not markedly seen but the shallow dimples seen on either side of the ligamentum patellae in an extended knee are obliterated.

MUSCLES OF THE MEDIAL COMPARTMENT OF THIGH

The medial compartment of the thigh lies behind the medial intermuscular septum and in front of the posterior inetrmuscular septum. The medial intermuscular septum is thin. Since this compartment is not bounded by clear fascial planes, it is not a true anatomic entity. It exists only in the upper part of the thigh and contains the adductor muscles. The muscles are:

- The gracilis
- The pectineus
- The adductor longus
- The adductor brevis
- The adductor magnus

Additional Notes on Gracilis

This slender muscle (Latin.gracilium=slender) is the most superficial of the adductor group. It is inserted into the upper part of the medial surface of the tibia as part of the pes anserinus. The muscle helps maintaining balance during walking

Additional Notes on Pectineus

This flat, quadrangular muscle forms part of the floor of the femoral triangle. It is sometimes considered to be a muscle of the anterior compartment. The femoral vessels and the great saphenous vein lie in front of this muscle. The muscle may be in two strata or laminae—ventral and dorsal. In such a case, the ventral lamina is supplied by the femoral nerve and the dorsal lamina by the obturator nerve.

Additional Notes on Adductor Longus

This muscle forms part of the floor of the femoral triangle. The medial border of this muscle forms the medial border

Table 23.3: Muscles of the medial compartment of thigh

Muscle	Origin	Insertion	Action	Nerve supply
Gracilis (Fig. 23.10)	Medial margin of pubic arch. The area includes parts of: • Body of pubis • Inferior ramus of pubis • Ramus of ischium	Upper part of medial surface of tibia (behind insertion of sartorius)	• Flexion of leg • Medial rotation of thigh • Adduction of thigh	Obturator nerve (L2, L3)
Pectineus (Fig. 23.11)	Superior ramus of pubis (pecten pubis and part of pectineal surface)	Posterior aspect of femur on a line passing from lesser trochanter to linea aspera (Fig. 23.12)	• Adduction of thigh • Flexion of thigh	• Femoral nerve • Obturator nerve (or accessory obturator nerve) (L2, L3)
Adductor longus (Figs 23.13 and 23.14)	Front of body of pub s	Posterior aspect of middle one-third of shaft of femur, into linea aspera between insertions of vastus medialis (medially) and of adductor brevis and adductor magnus (laterally)	• Adduct on of thigh • Flexion of thigh	Obturator nerve (anterior division) (L2, L3, L4)
Adductor brevis (Fig. 23.15)	From following parts of pubis: • Lower part of body • Inferior ramus (The origin is lateral to that of the gracilis and below that of adductor longus)	Posterior aspect of femur: • Along a line running from lesser trochanter to linea aspera • Upper part of linea aspera	• Adduction of thigh • Flexion of thigh • Role in rotation of thigh is controversial	Obturator nerve (L2, L3, L4)
Adductor magnus Adductor part (Fig. 23.16)	Mainly from ramus of ischium. Upper end of origin from ramus of pubis	• Medial margin of gluteal tuberosity • Linea aspera • Medial supracondylar line	Adduction of thigh	Obturator nerve (L2, L3, L4)
Hamstring part	Inferior and lateral part of ischial tuberosity (Fig. 23.17)	Adductor tubercle on medial condyle of tibia	Adduction of thigh may produce extension of thigh. Role in rotation of thigh is controversial	Sciatic nerve (tibial part) (L4)

of the tr angle. It is a fan-shaped muscle lying in the same plane as the pectineus. It arises by a tendon which is usually flattened. In some people, this tendon may be felt as a firm structure in the groin region. It may be strained or injured in sporting, cycling and riding activities. Its lower part forms the posterior wall of the adductor canal. Deep to it, there are adductor brevis and a small part of the adductor magnus. The femoral vessels and the great saphenous vein lie in front of this muscle. The spermatic cord crosses it near its origin. The profunda femoris vessels, and the anterior division of the obturator nerve, lie deep to it.

Additional Notes on Adductor Brevis

This muscle lies deep to the pectineus and adductor longus and superficial to the adductor magnus. The profunda femoris vessels and the anterior division of the obturator nerve lie in front of it. The posterior division of the obturator nerve is deep to it. The first and second perforating arter es (or sometimes only the second) pierce the muscle close to its femoral attachment.

Additional Notes on Adductor Magnus

This large, traingular muscle forms a partition separating structures on the front and medial side of thigh from those on the back of thigh. Structures anterior to it are—a. femoral vessels, b. profunda femoris vessels, c. obturator nerve, d. pectineus, adductor longus and adductor brevis muscles. The sciatic nerve and the hamstring muscles are posterior to it. Near the insertion of the muscle, there are a series of osseoaponeurotic apertures for passage of blood vessels. The largest and lowest of these is for the femoral vessels which enter the popliteal fossa at this point The

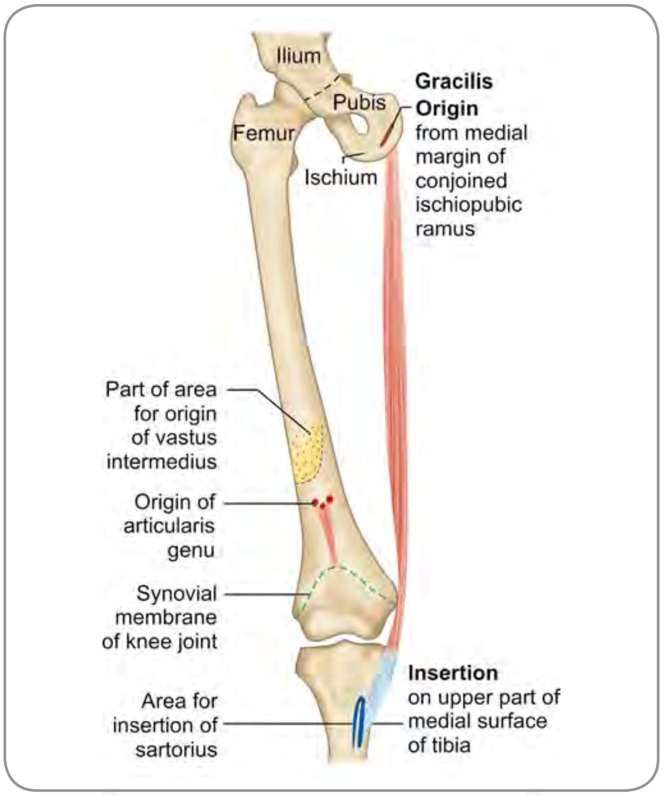


Fig. 23.10: Scheme to show attachments of the gracilis

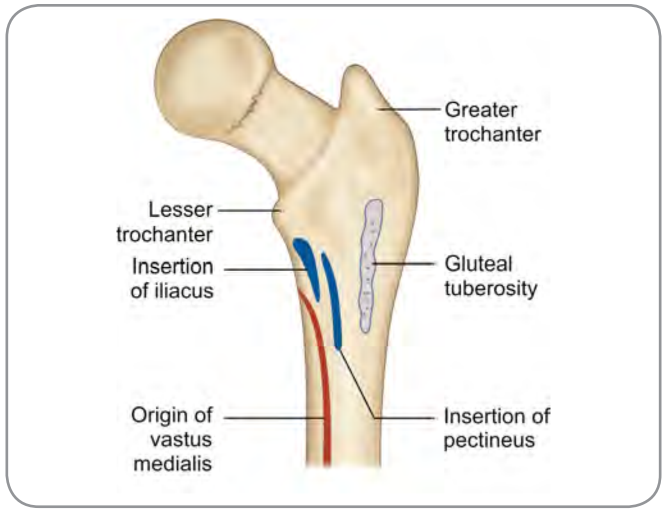


Fig. 23.12: Posterior aspect of upper end of femur showing insertion of pectineus and iliacus

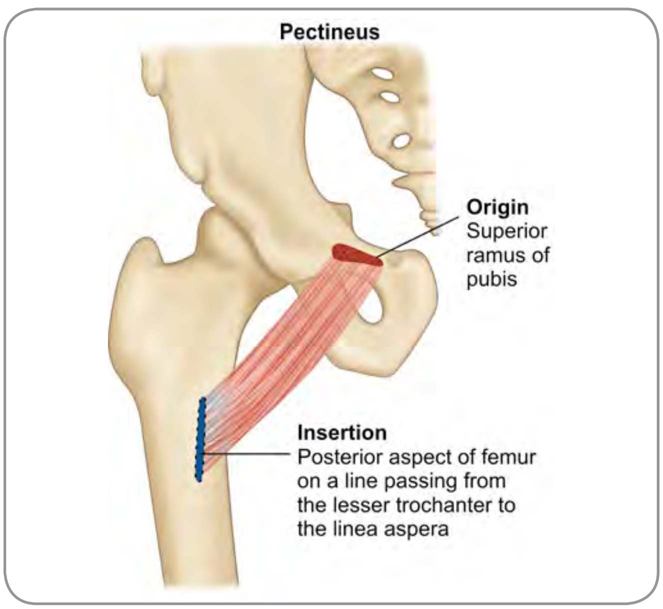


Fig. 23.11: Scheme to show attachments of the pectineus

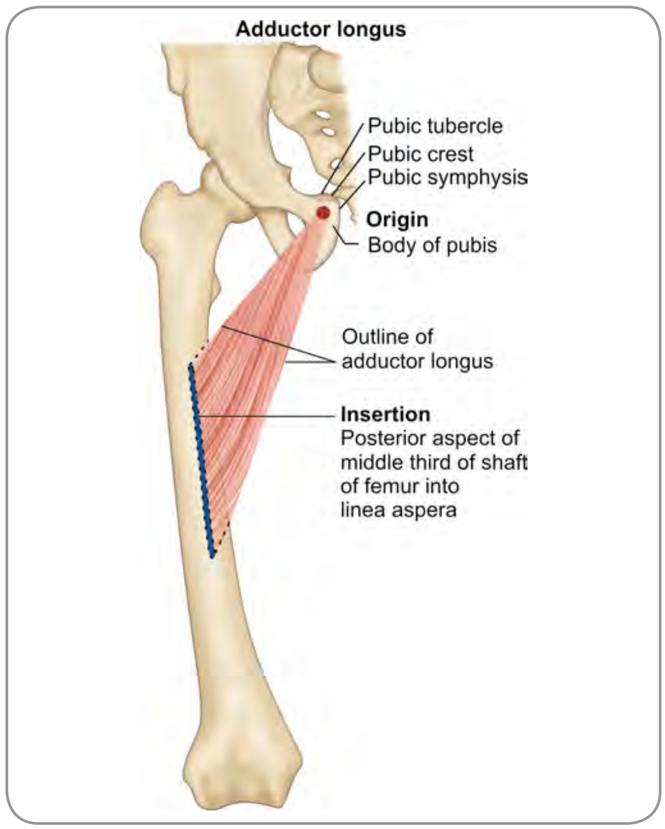


Fig. 23.13: Scheme to show attachments of the adductor longus

others are for the perforating arteries and the termination of the profunda femoris artery. The upper border of the adductor magnus may fuse with the lower border of the quadratus femoris. The superior part of the adductor magnus muscle has fibres originating from the pubic ramus and inserted into the gluteal tuberosity. This part is in an anterior plane compared to the rest of the muscle and is called the adductor minimus. Adductor magnus is customarily described as a muscle of both the medial and the posterior compartments. True to this, it has a dual

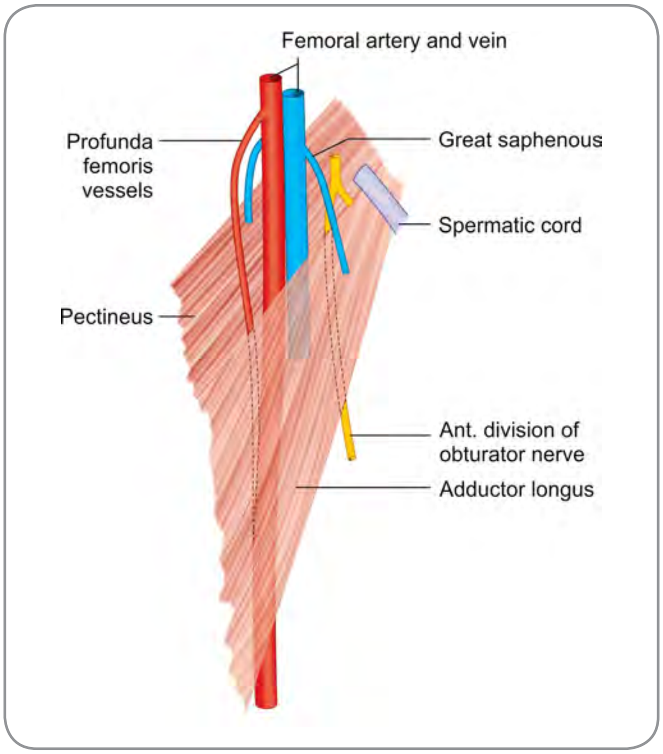


Fig. 23.14: Relations of the pectineus and of the adductor longus

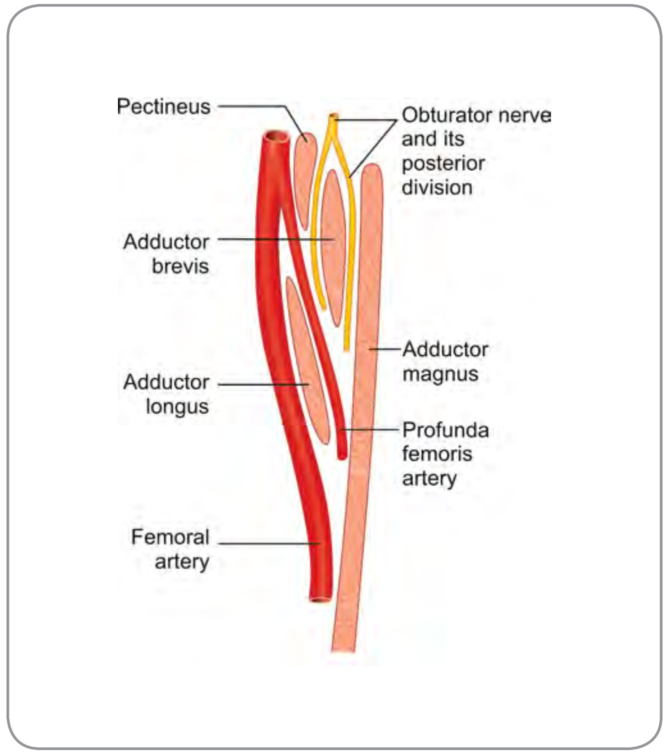


Fig. 23.16: Schematic ve tical section to show relations of the adductor muscles of the thigh

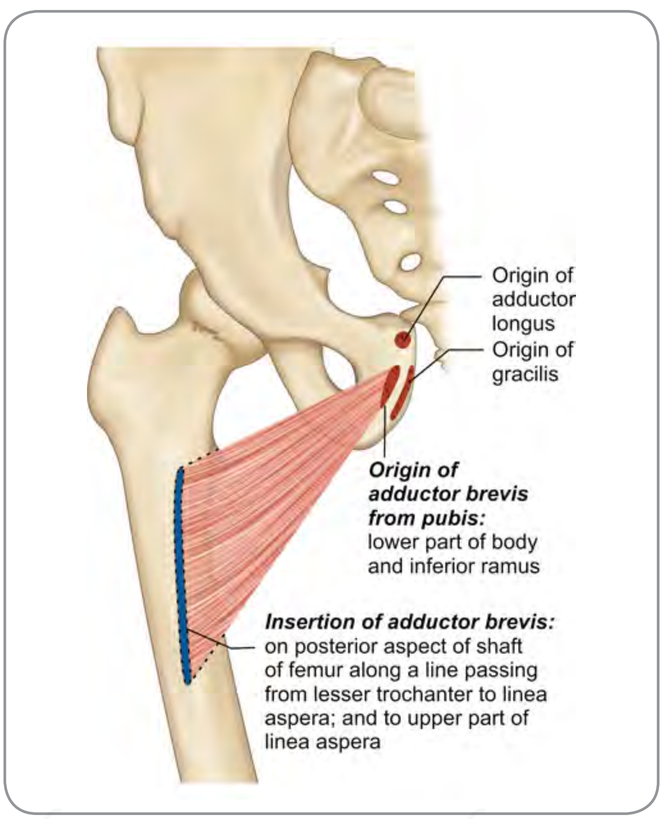


Fig 23.15: Scheme to show the attachments of the adductor brevis

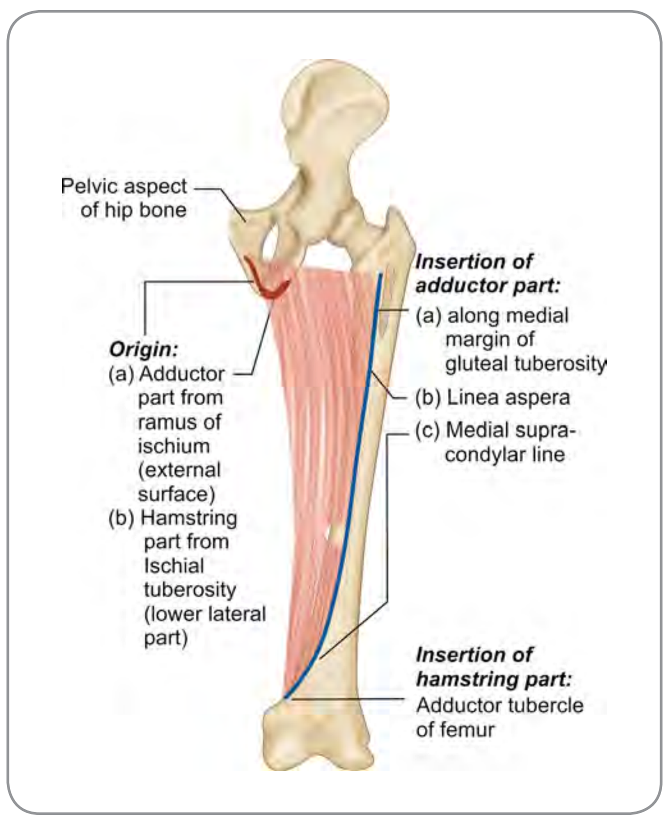


Fig. 23.17: Scheme to show the attachments of adductor magnus

Clinical Correlation

- ***Testing of the gracilis:*** The individual continues to flex the knee when the muscle is palpated for at the posteromedial aspect of the knee. Slight medial rotation of the thigh helps in making the muscle prominent.
- ***Testing of the adductors:*** With the individual in supine position and the knee extended, the adductors are tested by making the individual perform adduction of thigh against resistance.
- All the adductors including the gracilis but excluding the adductor magnus receive their main blood supply from a large branch of the profunda femoris artery called the 'artery to the adductors'. This artery sends main branches to supply the gracilis, adductor longus and brevis These branches form pedicles of musculocutaneous flaps involving the concerned muscles.
- Additional blood supply to these muscles is through branches of femoral or medial circumflex femoral or obturator arteries. Adductor magnus receives abundant blood supply from branches of profunda, medial circumflex femoral and femoral arteries on the anterior aspect and from branches of popliteal, medial circumflex and perforating arteries on the posterior aspect.
- The gracilis muscle is used in several muscle transplantation and replacement techniques. It is a weak muscle in the adductor group and does not subserve any major function. It is used (along with its blood and nerve supply) to replace any damaged muscle in the hand thus restoring digital functions.
- Strain, tears or avulsion tears of the adductor muscles often occur at their proximal attachments in aggressive sports. These are usually referred to as 'groin pulls'.
- Strains and tears of adductor longus are common in horse riders. The riders actively and constantly adduct their thighs to keep themselves secure on the animals; friction is produced leading to ossification of the tendons or formation of small bones. Such additional bones are referred to as ***'riders bones'***.
- In some neurological disorders, the adductor muscles of the thigh go into painful spasm. The spasm can be relieved by cutting the tendon of the adductor longus (adductor tenotomy) or by crushing the obturator nerve.

nerve supply: the upper and middle portions of the muscle supplied by the obturator nerve (adductor component) and the ischiocondylar portion supplied by the tibial division of the sciatic nerve (hamstring component). Both nerves are derived from the anterior divisons of the lumbosacral plexus and thus indicate a flexor origin for both parts of the muscle.

Actions of the adductors: Since great degrees of adduction of the hip are not required, the adductors act more during various types of gait movements and in controlling posture.

Morphological Factors

- Coracobrachialis is the homologue of the adductor group of muscles in the upper limb.

contd...

contd...

- The adductor group forms a larger and stronger mass than the coracobrachialis due to their active participation in the maintenance of posture and gait. They also neutralise unwanted movements which may occur du ing gait.
- The obturator externus muscle, due to its location and nerve supply, is included in the adductor group by the clinicians. Though morphologically it appears to be an 'obturator territory' muscle, functionally it is one of the small lateral rotators of the thigh and abducts a flexed thigh. It is preferable to classify this muscle as that of the iliac region or the gluteal region.
- The gracilis, along with the other two pes anserinus members (Sartorius and semitendinosus), provides stability to the medial aspect of the extended knee. The corresponding functional homologues on the lateral aspect are the gluteus maximus and tensor fasciae latae which provide stability to the lateral aspect of the extended knee.

Adductor Canal

The adductor canal, otherwise called the ***subsartorial canal*** or the ***Hunter's canal***, is a musculoaponeurotic tunnel in the middle third of the thigh. It extends from the apex of the femoral triangle to an osseofibrotic opening in the adductor magnus through which the femoral vessels pass into the popliteal fossa (the opening is often called the adductor hiatus).

The canal is triangular in cross-section; its walls are formed as follows:

- ***Anterolaterally*** by the vastus medialis;
- ***Anteromedially*** by a strong fibrous membrane (***vastoadductor fascia***) extending from the adductors to the vastus medialis and lying deep to sartorius;
- ***Posteriorly*** by the adductor longus (above) and the adductor magnus (below).

It should be remembered that the vastus medialis inserts into the medial lip of linea aspera in the middle third of the thigh. The adductor longus and adductor magnus also insert into the linea aspera immediately lateral to the insertion of vastus medialis. As the main bulk of the vastus medialis curves anteriorly and the adductors curve posteriorly, a muscular gutter is created between the two. The vasoadductor fascia stretches between the medial aspect of vastus medialis to the adductors thus converting the gutter into a canal. The strong membrane is reinforced by the presence of the sartorius muscle superficial to it. Since the gutter provides an intermuscular passage for the femoral vessels and related structures, it is labelled as the floor of the canal and the vasoadductor fascia is called the roof of the canal.

The contents of the canal are:

- The femoral artery and vein where the vein lies posterior to the femoral artery in the upper part of the canal, and

lateral to it in the lower part. At the lower end of the canal the femoral vessels pass through the adductor hiatus to reach the popliteal fossa.

- The ***saphenous nerve*** runs along the femoral artery, gradually crossing it from lateral to medial side. At the lower end of the canal, the nerve pierces the fibrous roof to become superficial.
- The branch of the femoral nerve to the vastus medialis runs downwards lateral to the femoral artery.
- Some branches of the obturator nerve may descend along the femoral artery.

The ***subsartorial plexus of nerves*** lies over the fascia forming the roof of the adductor canal. The plexus receives contributions from the medial cutaneous nerve of the thigh, the saphenous nerve, and the anterior division of the obturator nerve.

Clinical Correlation

The adductor canal is a region of surgical importance. The femoral artery can be easily approached here. Only the sartorius muscle needs to be retracted and the femoral artery can be reached by opening the vasoadductor fascia. The canal has been named after John Hunter, an 18th century Scottish surgeon. Hunter is supposed to have ligated the femoral artery in the canal as a treatment for popliteal aneurysm

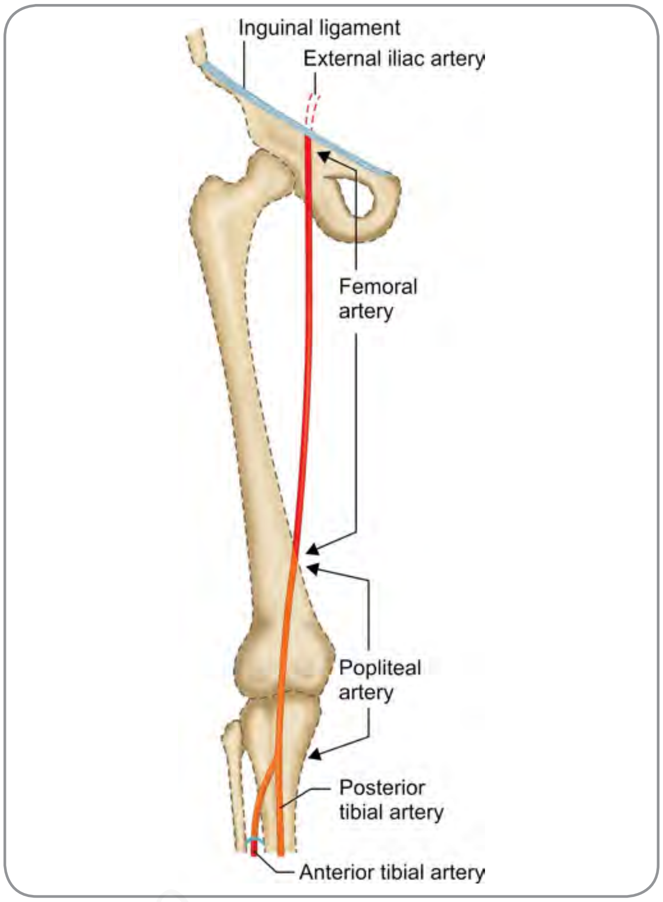


Fig. 23.18: Main arteries in the thigh and upper part of the leg

FEMORAL ARTERY (FIGS 23.18 AND 23.19)

The femoral artery is the artery of the anterior compartment of the thigh and the primary artery of the lower limb (Fig. 23.18). It is the continuation of the external iliac artery into the thigh. It begins at the midinguinal point (i.e., midway between the pubic symphysis and the anterior superior iliac spine) and descends first in the anterior compartment of the thigh (upper third of thigh) and then in the adductor canal (middle third of thigh). It ends at the junction of the middle and lower thirds of the thigh as it passes through the adductor hiatus to become the ***popliteal artery.***

Therefore, the artery can be described in two parts; the proximal part that lies in the femoral tr angle (Fig. 23.19) and the distal part that courses through the adductor canal. Clinically too, two parts of the femoral artery are described which however differ from the anatomical description. That part of the artery proximal to the origin of the profunda femoris artery is labelled the common femoral artery and that part distal to the origin of profunda is the superficial femoral artery.

Relations of the femoral artery in the femoral triangle: The first 3 to 4 cm of the femoral artery along with the femoral vein are enclosed in the femoral sheath

- Within the triangle, the femoral artery lies successively over the—a. psoas major, b. pectineus, and c. adductor

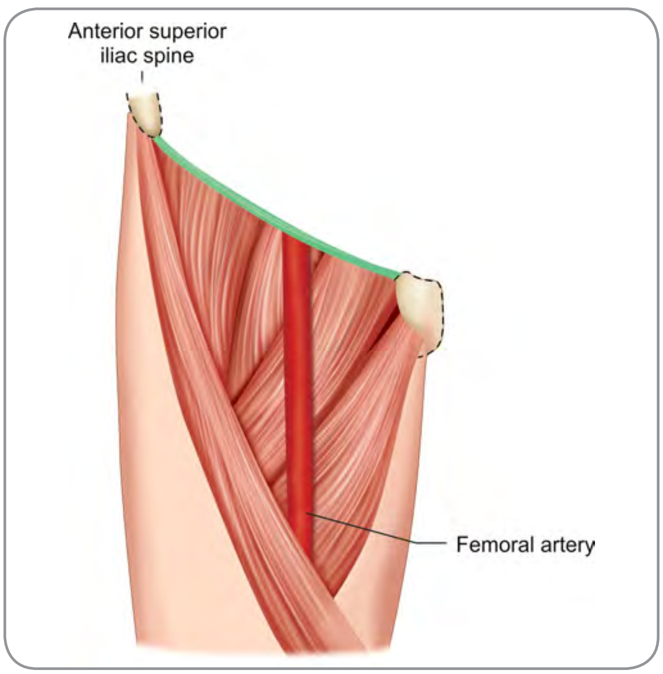


Fig. 23.19 Femoral artery in femoral triangle

longus. The psoas tendon separates it from the hip joint, femoral vein and profunda vessels separate it from the pectineus muscle and the femoral vein separates it from the adductor longus.

- It is covered by skin, superficial and deep fascia.
- The superficial circumflex iliac vein crosses in the superficial fascia.

The femoral artery is accompanied by the femoral vein. Just below the inguinal ligament, the vein is medial to the artery. However, the vein gradually crosses to the lateral side posterior to artery (Fig. 23.20). It is directly behind the artery at the apex of the femoral triangle.

The femoral nerve is lateral to the upper part of the artery. Lower down, the artery is related to the branches of the nerve, some of which cross it. The branch to the pectineus crosses behind the upper part of the artery. The femoral branch of the genitofemoral nerve is also lateral to the upper part of the femoral artery (within the femoral sheath), but lower down it passes to the front of the artery. The medial cutaneous nerve of the thigh crosses the artery from lateral to medial side near the apex of the femoral triangle.

Relations of the femoral artery in the adductor canal (Fig. 23.21):

The femoral artery runs through the adductor canal.

- Anterior to the artery are the skin, superficial fascia, deep fascia, sartorius and the vasoadductor fascia.
- Posterior are the adductor longus and adductor magnus muscles.

The femoral vein is posterior in the proximal part of the canal and is lateral in the distal part.

The saphenous branch of the femoral nerve crosses the artery within the canal. The nerve to vastus medialis is also lateral to the artery in the canal (Fig. 23.22).

Branches of the femoral artery (Fig. 23.23)

The first three branches are superficial and the remaining are deep.

Superficial branches: They arise from the femoral artery just below the inguinal ligament; piercing the femoral sheath and the cribriform fascia they become subcutaneous. Their further courses are as follows:

- The ***superficial epigastric*** artery ascends across the inguinal ligament and then runs upwards and medially towards the umbilicus.
- The ***superficial circumflex iliac*** artery is the smallest of the superficial branches. It turns laterally, runs towards the anterior superior iliac spine and supplies the skin and superficial fascia of the area.
- The ***superficial external pudendal*** artery runs medially to supply the skin over the external genitalia and over the lower part of the abdomen.

Deep branches:

- The deep external pudendal artery, profunda femoris artery and some muscular branches are the deep branches in the proximal part of thigh.
  - The ***deep external pudendal*** artery runs medially deep to the fascia lata. It becomes superficial after crossing the adductor longus and supplies the external genitalia.
  - Muscular branches to sartorius, vastus medialis, adductor brevis, adductor longus and adductor magnus.

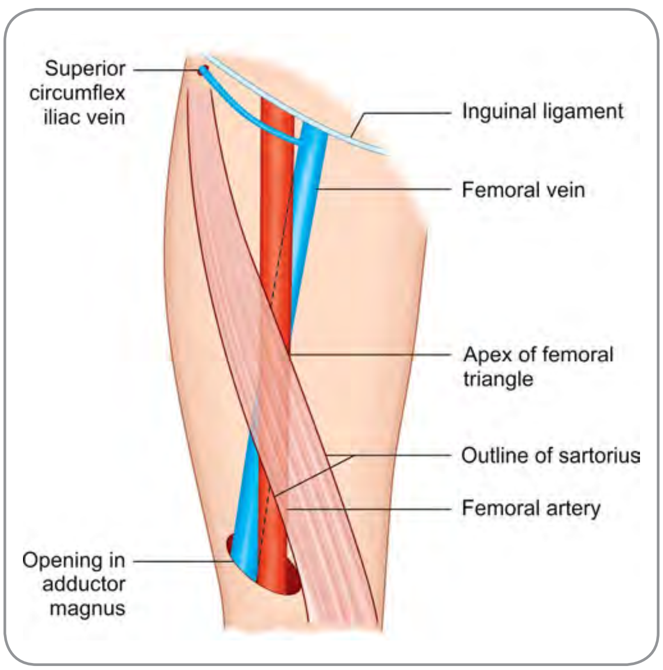


Fig. 23.20: Relationship of femoral artery to femoral vein

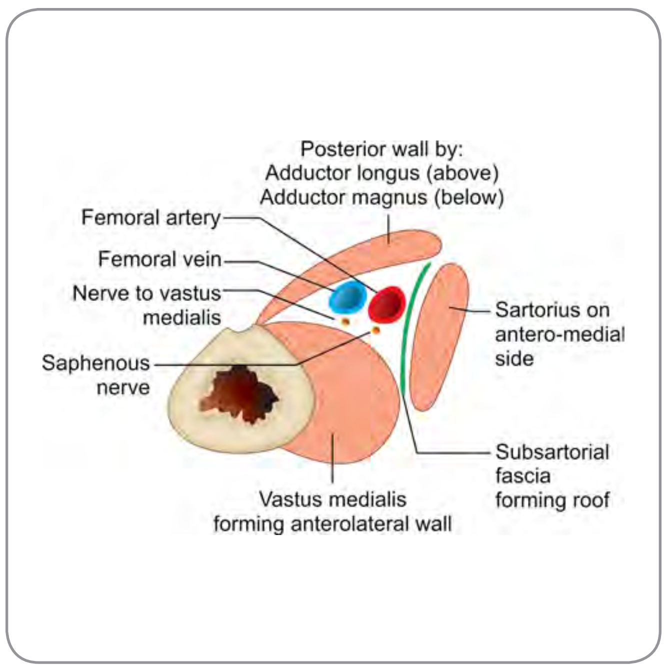


Fig. 23.21: Femoral vessel in adductor canal; Bounderies of the canal are shown

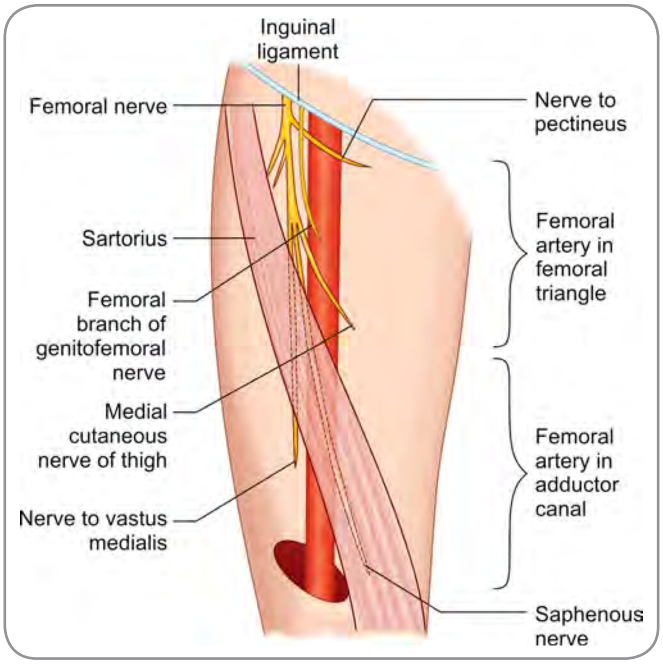


Fig. 23.22: Relationship of femoral artery to femoral nerve and its branches

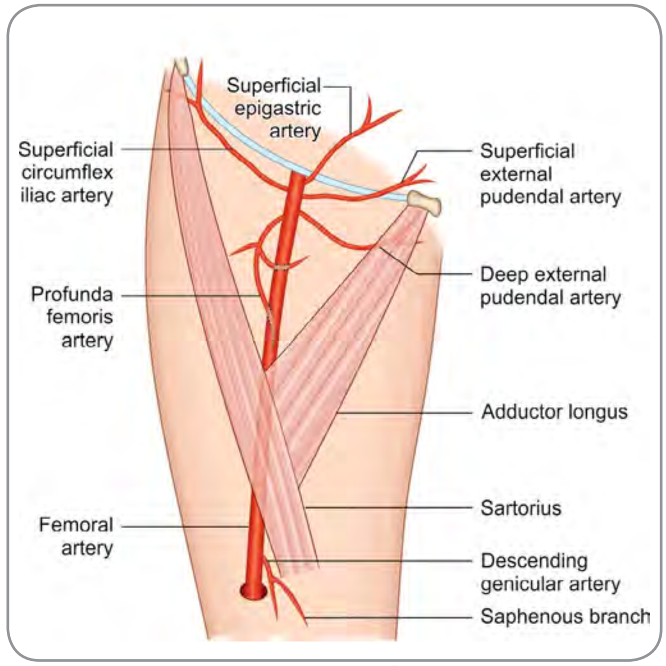


Fig. 23.23: Branches of femoral artery

- The ***profunda femoris*** artery is the largest branch of the femoral artery and is the main artery of supply for the muscles of the thigh.

- The deep branch in the adductor canal is the descending genicular artery. It arises proximal to the adductor opening and immediately gives out a saphenous branch. Descending in the vastus medialis it reaches the medial side of the knee and anastomoses with the medial superior genicular artery. It gives muscular branches to the vastus medialis and adductor magnus. Articular branches join the anastomosis around the knee and supply the knee joint. The saphenous branch, called the saphenous artery, accompanies the saphenous nerve through the adductor canal, pierces the roof of the canal to reach the subcutaneous plane and supplies the skin over the upper and medial part of the leg.

Profunda Femoris Artery

The profunda femoris (the deep femoral artery; Latin. profunder=depth, profundus=deep) arises from the lateral side of the femoral artery, 3 to 4 cm below the inguinal ligament. It first descends lateral to the femoral vessels and then spirals around to become posterior. It then passes between the pectineus and adductor longus, between the adductor longus and the adductor brevis and then between the adductor longus and the adductor magnus. It then passes through an osseofibrous opening in the insertion of the adductor magnus to each the posterior aspect and ends by anastomosing with branches of popliteal artery. It is called the fourth perforating artery as it passes through the osseofibrous opening.

Relations of profunda femoris artery: Anterior to the profunda is the femoral artery which is separated by the femoral and profunda veins and the adductor longus muscle. Lateral to the profunda is the vastus med alis muscle. Posterior to the profunda (from above downwards) are the iliacus, pectineus, adductor brevis and adductor magnus (Fig. 23.24).

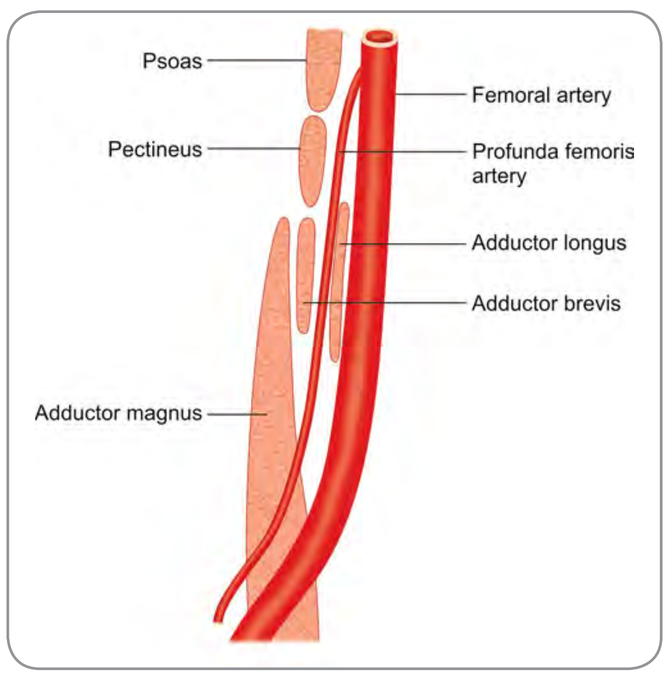


Fig 23.24: Relations of profunda femoris artery

Branches of Profunda Femoris Artery (Fig. 23.25)

Medial Circumflex Femoral Artery

- The medial circumflex femoral artery arises from the posteromedial aspect of the profunda. It winds around the medial side of the femur passing through various muscles and emerges on the back of thigh between the upper border of the adductor magnus and the quadratus femoris. It then divides into transverse and ascending branches. The transverse branch participates in the cruciate anastomosis. The ascending branch ascends up on the obturator externus to the trochanteric fossa and anastomoses with branches of the gluteal and lateral circumflex femoral arteries. An acetabular branch from the medial circumflex femoral artery supplies the acetabular fossa and the femoral head.

Lateral Circumflex Femoral Artery

- The lateral circumflex femoral artery arises from near the root of profunda. It passes between the divisions of the femoral nerve and posterior to the sartorius and rectus. It divides into an ascending, a transverse and a descending branch. The ***ascending branch*** passes laterally to the lateral side of the hip joint and participates in an anastomotic ring around the femoral neck. The ***transverse branch,*** passing through the muscles of the area, winds around the lateral side of the femur and takes part in the cruciate anastomosis. The ***descending branch*** runs downwards behind the rectus femoris and along the vastus lateralis. Its branches reach the knee and participate in the anastomosis around the knee.

Perforating Arteries (Fig. 23.26)

The perforating branches pass through several muscles attached to the femur, at or near the linea aspera and reach the flexor aspect of the thigh. There are three perforating branches and the profunda itself becomes the fourth perforating artery. After giving out muscular, cutaneous and anastomotic branches, they reduce in size, pierce the lateral intermuscular septum and end in the substance of the vastus lateralis.

- The first perforating artery arises proximal to the adductor brevis; supplies the adductor brevis, adductor magnus, biceps femoris and gluteus maximus; anatomoses with the inferior gluteal artery through an ascending branch and with the second perforating through a descending branch.
- The second perforating artery arises anterior to the adductor brevis; supplies the posterior thigh muscles; anastomoses with the first and third perforating arteries through the ascending and descending branches respectively.
- The third perforating artery arises distal to the adductor brevis; supplies the posterior thigh muscles; anastomoses with the second perforating and the profunda femoris through the ascending and descending branches respectively.

These anastomoses provide an important collateral circulation, if the femoral artery is blocked. The anastomosis

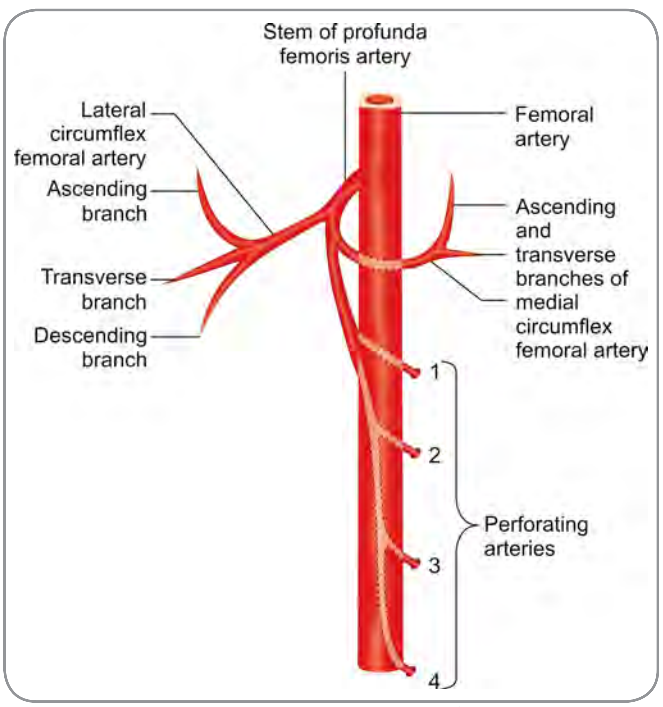


Fig. 23.25: Branches of profunda femoris artery

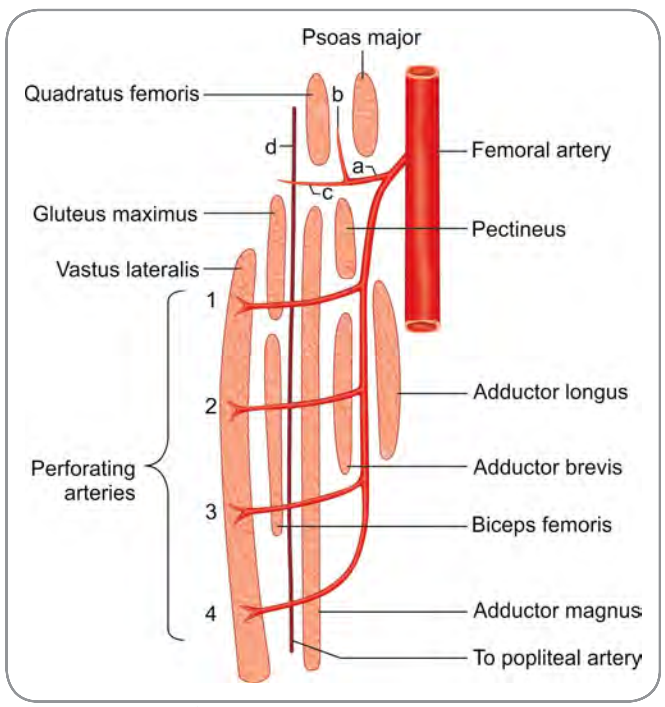


Fig. 23.26: Perforating arteries; a = medial circumflex artery, b = ascending branch, c = transverse branch, d = anastomosing branch of inferior gluteal artery

is actually in the form of a double chain—one in the adductor muscles and another close to the linea aspera.

Muscular Branches

Numerous branches of the profunda supply the muscles of the thigh. The profunda is the main supply to the femoral muscles.

Added Information

The medial circumflex femoral artery is specially important; it supplies blood to the head and neck of femur through its posterior retinacular branches.

Clinical Correlation

- Pulsations of the femoral artery can be felt just below the midinguinal point.
- The artery can be also pressed against the superior ischiopubic ramus at this point to stop bleeding.
- The femoral artery is covered only by skin and fasciae during its course in the femoral triangle. This fact makes it vulnerable to injuries and damage. Lacerated wounds of the anterior thigh can damage both the artery and the vein often leading to an arteriovenous shunt.

Use of femoral artery for arteriography: The femoral artery is used for inserting a catheter that is passed through the external iliac and common iliac arteries into the aorta. It can then be passed into one of the branches of the aorta. The catheter can be used for injecting a suitable contrast medium into the artery. A radiograph taken immediately after the injection displays the branches of the artery into which the dye is injected. The procedure is called angiography. Points of narrowing of the artery can be detected. A suitable catheter passed through the aorta can reach the opening of a coronary artery. Dye injected can outline the coronary artery and any points of narrowing can be seen Catheters introduced into an artery can also be used for recording pressures within the vessel, and for obtaining samples for analysis of blood gases.

FEMORAL VEIN

The femoral vein commences as a continuation of the popliteal vein at the adductor hiatus and terminates posterior to the inguinal ligament as the external iliac vein. The relationship of the femoral vein to the femoral artery is important. In the distal adductor canal, it is posterolateral to the artery; in the proximal adductor canal and in the apex of the femoral triangle, it is posterior; in the upper part of the femoral triangle, it is medial. It occupies the middle compartment of the femoral sheath. The free space available because of the femoral canal allows for expansion of he vein.

Its tributaries are as follows (Fig. 23.27):

- Muscular tributaries – from various muscles;
- Profunda femoris vein – joins the femoral vein posteriorly about 10 cm distal to the inguinal ligament; it has tributaries corresponding to the arterial branches;
- Great saphenous vein – joins the femoral vein at the level of the saphenous opening;
- Medial and lateral circumflex femoral veins – these veins generally open directly into the femoral vein and not through the profunda femoris vein.

The veins accompanying the superficial branches of the femoral artery (viz the superficial circumflex iliac, the superficial epigastric and the superficial external pudendal arteries) end in the great saphenous vein and not directly into the femoral vein.

NERVES OF THE ANTERIOR AND MEDIAL COMPARTMENTS OF THIGH

The nerves of the anterior and the medial compartments of thigh are branches of the lumbar plexus. The plexus will be studied in detail when the study of abdomen is taken up. However, certain requisite details will now be discussed.

Lumbar Plexus (Fig 23.28)

The lumbar plexus is formed by the upper four lumbar nerves with a contribution from the twelfth thoracic spinal nerve. After emerging from the intervertebral foramina each nerve divides into a dorsal ramus and a ventral ramus. The ***dorsal rami*** of lumbar (and sacral nerves) contribute to the cutaneous nerve supply of the gluteal region.

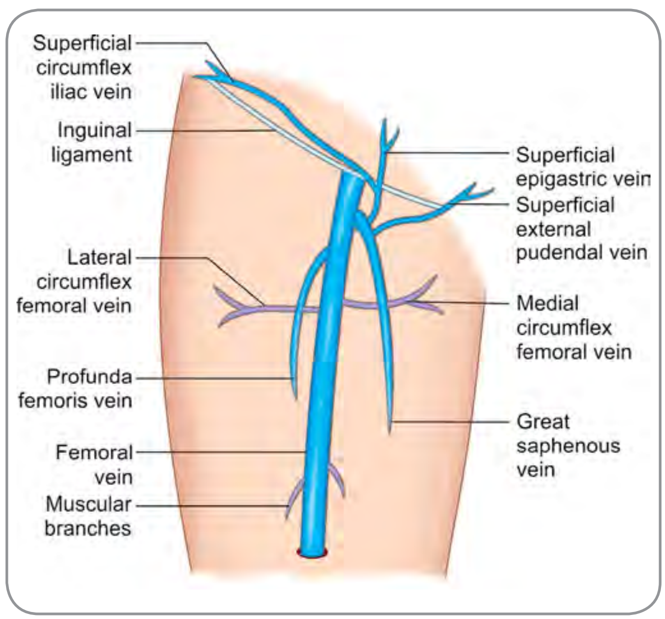


Fig. 23.27: Tr butaries of femoral vein

The ***ventral rami*** enter the substance of the psoas major muscle. Within the muscle, the rami from the upper four lumbar nerves join each other to form the ***lumbar plexus.*** Part of the fourth lumbar nerve joins the fifth lumbar to form the lumbosacral trunk which takes part in forming the sacral plexus.

The greater part of the first lumbar nerve is continued into a nerve trunk that divides into the ***iliohypogastric*** and ***ilioinguinal*** nerves. The rest of the first lumbar nerve is joined by a branch from the second lumbar to form the ***genitofemoral*** nerve.

The second, third and the greater part of the fourth lumbar nerve divide into ***anterior*** and ***posterior divisions***. The posterior divisions (which are large) form the ***femoral nerve***. The posterior divisions of L2 and L3 also give rise to the ***lateral cutaneous nerve of the thigh***. The anterior divisions unite to form the ***obturator nerve***.

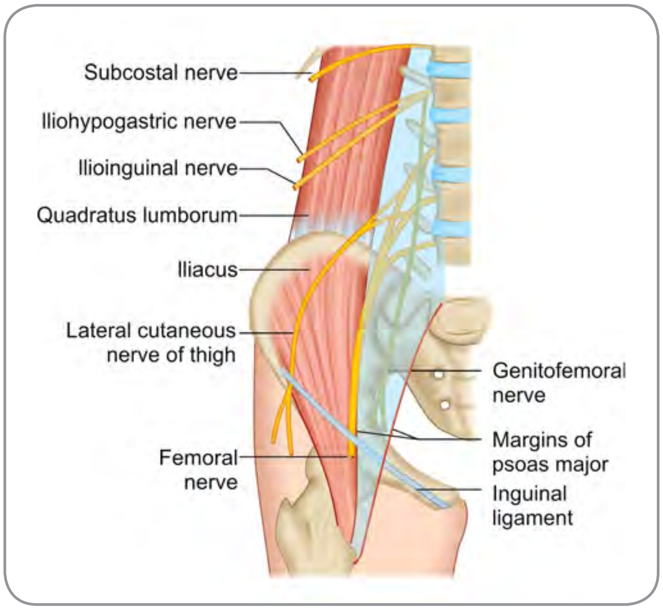


Fig. 23.29: Scheme to show some branches of the lumbar plexus as they lie on the posterior abdominal wall

Nerves Encountered in the Anterior and Medial Compartments

Ilioinguinal Nerve (Fig. 23.29)

Terminal twigs of the ilioinguinal nerve supply the skin of the upper and medial part of the thigh.

Genitofemoral Nerve (Fig. 23.30)

The genitofemoral nerve (L1, L2) runs downwards first in the substance of the psoas major and then on its anterior surface. The nerve passes deep to the ureter. It ends by dividing into genital and femoral branches. The ***genital branch*** comes into relationship with the lateral side of the external iliac artery. It crosses in front of the lower part

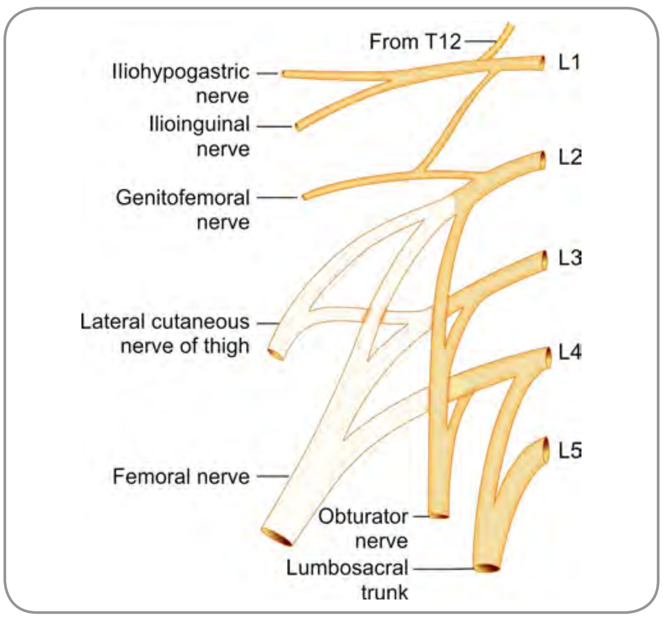


Fig. 23.28: Scheme to show the lumbar plexus and its branches

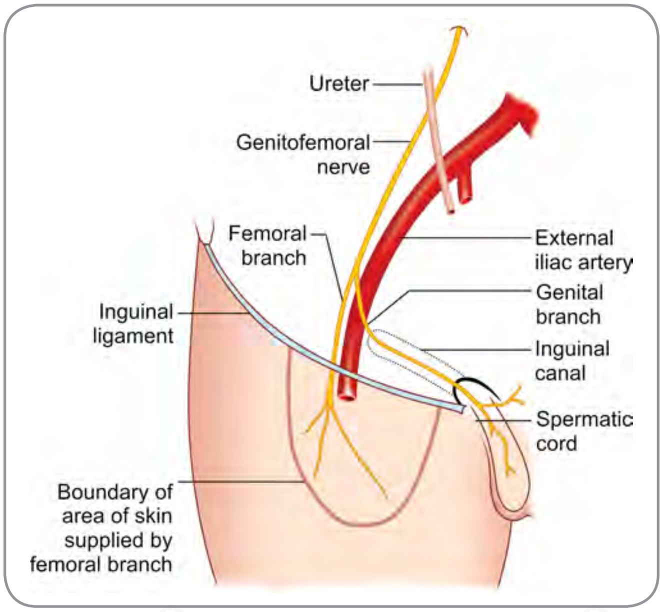


Fig. 23.30: Scheme to show the course of the genitofemoral nerve

of the artery and enters the inguinal canal through the deep inguinal ring. The nerve supplies the cremaster and dartos muscles and gives some branches to the skin of the scrotum or of the labium majus (Fig. 23.30).

The ***femoral branch*** continues to descend on the lateral side of the external iliac artery. It passes deep to the inguinal ligament and comes to lie lateral to the femoral artery. Here, it lies within the femoral sheath. It becomes superficial by piercing the anterior wall of the sheath and the deep fascia and supplies an area of skin over the upper part of the femoral triangle.

Lateral Cutaneous Nerve of Thigh

The lateral cutaneous nerve of the thigh is derived from the dorsal divisions of L2 and L3 Its initial part lies within the psoas major. Emerging from the lateral border of the muscle the nerve runs downwards, laterally and forwards over the iliacus muscle to reach the anterior superior iliac spine. It enters the thigh by passing behind the lateral end of the inguinal ligament. It divides into anterior and posterior branches through which it supplies the skin on the anterolateral part of the thigh right up to the knee. While the nerve is over the iliacus muscle, it is related to the caecum on the right side and to the part of the descending colon on the left side.

Obturator Nerve (Figs 23.31 and 23.32)

The obturator nerve is formed by union of roots arising from L2, L3, and L4. For convenience of description, its course can be considered in three parts.

- The first part runs downwards in the substance of the psoas major. It emerges at the medial border of psoas major; passing lateral to the internal iliac vessels, it enters the pelvic cavity.
- The second part of the nerve lies in the lateral wall of the true pelvis. It runs downwards and forwards lying over the obturator internus muscle. This part of the nerve is crossed by the internal iliac artery and vein. It is accompanied by the obturator vessels which lie below and behind it. It leaves the lateral wall of the pelvis by passing through the upper part of the obturator foramen to enter the thigh (Fig. 23 27).
- The third part of the nerve lies in the thigh. As it passes through the obturator foramen, it divides into anterior and posterior divisions.
  - The anterior division lies in front of the obturator externus (above) and the adductor brevis (below). It lies behind the pectineus (above) and the adductor longus (below).
  - The posterior division lies in front of the obturator externus (above) and the adductor magnus (below). It is behind the pectineus (above) and the adductor brevis (below).

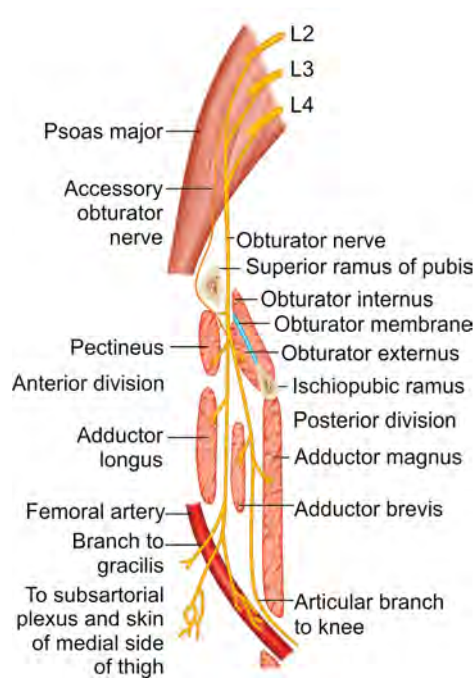


Fig. 23.31: Scheme to show the course and distribution of the obturator nerve

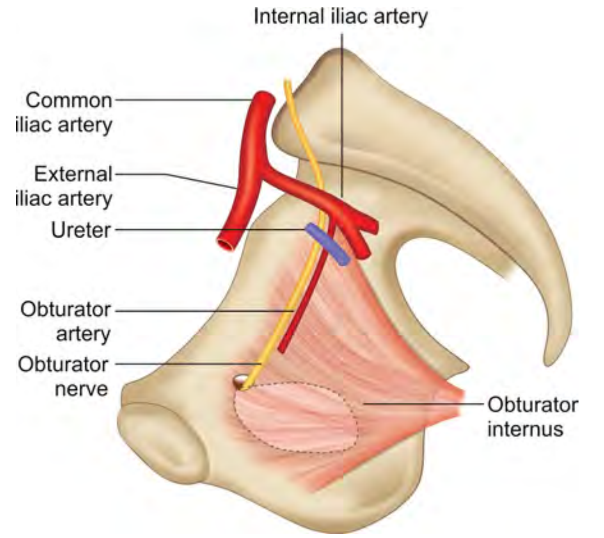


Fig. 23.32: Lateral wall of true pelvis showing the obturator nerve and some related structures

The obturator nerve is distributed as follows:

Muscular branches:

- Branches arising from the anterior division supply:
  - Obturator externus
  - Adductor longus
  - Gracilis
  - Pectineus
  - Adductor brevis (sometimes).
- Branches of the posterior division supply:
  - Obturator externus
  - Adductor brevis
  - Adductor magnus.

Cutaneous branches: After supplying the muscles named above the anterior division supplies the skin of the lower medial part of the thigh. (These fibres may reach the skin through a branch that joins the medial cutaneous and saphenous branches of the femoral nerve to form the ***subsartorial plexus***).

Articular branches: These are given off to the hip joint and to the knee joint. The latter is a continuation of the posterior division and travels along the femoral artery.

Vascular branches: The anterior division ends by supplying the femoral artery

Accessory Obturator Nerve

Occasionally, some fibres of the obturator nerve follow a separate course and are termed the ***accessory obturator nerve***. Arising from L2 and L3, this nerve runs downwards along the medial margin of the psoas major in company with the external iliac vessels. It does not enter the true pelvis but passes behind the inguinal ligament (deep to the pectineus) to reach the thigh. The nerve ends by supplying the pectineus and the hip joint and communicates with the anterior division of the obturator nerve.

Femoral Nerve (Fig. 23.33)

The femoral nerve arises from the ventral rami of spinal nerves L2, L3 and L4 within the substance of the psoas major. It descends through this muscle and emerges from its lateral border a few centimetres above the inguinal ligament. It then comes to lie in the groove between the iliacus (laterally) and the psoas (medially). In this position, it passes behind the inguinal ligament to enter the thigh. Here, it lies lateral to the femoral artery. After a short course, it ends by dividing into anterior and posterior divisions. The distribution of the femoral nerve is as follows:

Muscular Branches (Fig. 23.33)

- While still in the abdomen, the femoral nerve gives branches to the iliacus.
- A little above the inguinal ligament, it gives off the ***nerve to the pectineus***. This nerve passes downwards and medially ***behind*** the femoral vessels to reach the pectineus.
- A branch from the anterior division of the femoral nerve supplies the sartorius. This branch arises in common with the intermediate cutaneous nerve of the thigh.
- Branches of the posterior division of the femoral nerve supply:
  - Rectus femoris
  - Vastus lateralis
  - Vastus medialis
  - Vastus intermedius.

Cutaneous Branches (Fig. 23.34)

- The ***intermediate cutaneous nerve of the thigh*** arises from the anterior division of the femoral nerve. It supplies a broad strip of skin on the front of thigh. The lower end of the area reaches the front of the knee.
- The ***medial cutaneous nerve of the thigh*** is a branch of the anterior division of the femoral nerve. It first lies along the lateral side of the femoral artery which it crosses near the apex of the femoral triangle. It divides into branches that supply the skin of the medial side of the thigh. The nerve takes part in forming the ***subsartorial plexus*** (along with branches of the saphenous and obturator nerves).
- The ***saphenous nerve*** arises from the posterior division of the femoral nerve. It descends along the lateral side of the femoral artery. In the adductor canal, the nerve crosses the artery from lateral to medial side. It leaves the adductor canal at its lower end and runs down along the medial side of the knee. Here, it pierces the

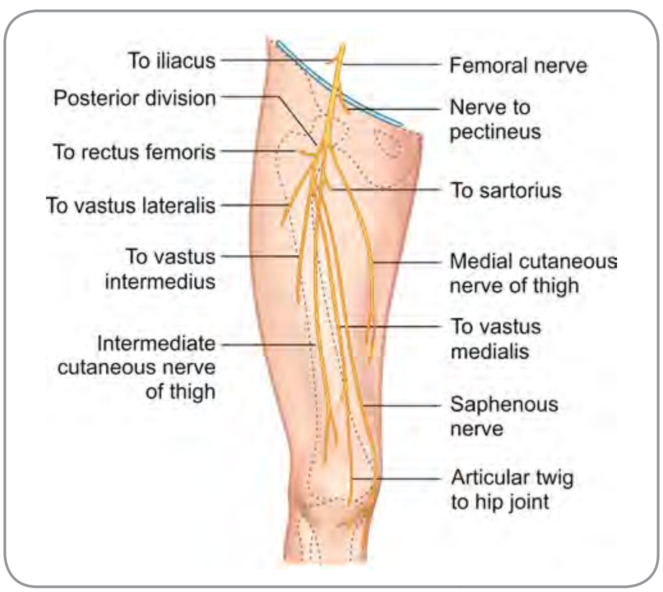


Fig. 23.33: Scheme to show the distribution of the femoral nerve in the thigh

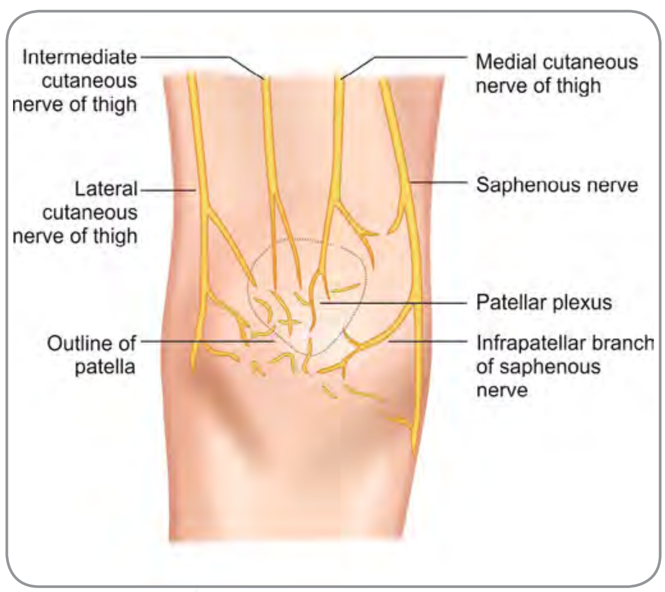


Fig. 23 34 Cutaneous branches of femoral nerve

deep fascia and becomes subcutaneous. It then runs down the medial side of the leg (alongside the long saphenous vein). A branch extends along the medial side of the foot (but ends short of the great toe). The saphenous nerve takes part in forming the subsartorial plexus and the ***patellar plexus*** (Fig. 23.34).

Articular branches The posterior division of the femoral nerve sends fibres to the knee joint through the nerve to the vastus medialis. Some fibres reach the hip joint through the nerve to the rectus femoris.

Vascular branches: These reach the femoral artery and its branches.

Multiple Choice Questions

1. Saphenous opening is formed by:
   a. Overlap of the two strata of cribriform fascia
   b. Overlap of the two strata of iliotibial tract
   c. Overlap of the two strata of fasciae latae
   d. Overlap of the two strata of superficial fascia

2. What is false about the femoral branch of the genitofemoral nerve?
   a. It is given out above the inguinal ligament
   b. It supplies skin over the upper part of femoral triangle
   c. It pierces the posterior layer of femoral sheath
   d. It runs down anterior to the femoral artery

3. The muscle that acts on the hip and the knee is:
   a. Articularis genu
   b. Vastus medialis
   c. Vastus intermedius
   d. Rectus femoris

4. The structure that separates the femoral artery from the hip joint is:
   a. Pectineus muscle
   b. Psoas major tendon
   c. Femoral vein
   d. Profunda femoris artery

5. A branch of the posterior division of femoral nerve is:
   a. Nerve to pectineus
   b. Intermediate cutaneous nerve of thigh
   c. Saphenous nerve
   d. Muscular branch to iliacus

ANSWERS

1 c **2.** c **3.** d **4.** b **5.** c

Clinical Problem-solving

Case Study 1: A 56-year-old fat lady presented with a swelling below and lateral to the pubic tubercle. On close examination, the swelling appeared globular with a small extension superolaterally.

- What do you think is the cause for the swelling?
- In what way is the lady more prone to develop this condition?
- What are the 'normal' contents of the femoral canal?

Case Study 2: A 45-year-old horse jockey complained of pain and swelling on the medial aspect of his left thigh. On close examination, small firm areas could be palpated on the anteromedial aspect of the patients thigh:

- What is the probable diagnosis?
- Why should the thigh adductors be specifically affected in a horse rider?
- What are the supernumerary bones formed in such a condition called?

(For solutions see Appendix).

Chapter **24**

Gluteal Region and Back of Thigh

Frequently Asked Questions

- Enumerate the structures under the cover of gluteus maximus.
- Discuss the gluteus maximus muscle.
- Write notes on—
  - Gluteus medius and minimus
  - Short lateral rotators of thigh
  - Piriformis
  - Trendelenberg sign
  - Trochanteric anastomosis
  - PIN structures
  - Superior gluteal artery
  - Inferior gluteal artery
  - Cruciate anastomosis
  - Posterior cutaneous nerve of thigh
  - Gemelli muscles
- Discuss the sciatic nerve in the thigh region.
- Discuss the hamstring muscle.
- Describe the arterial anastomosis in the back of thigh.

GLUTEAL REGION

The gluteal region (Greek.gluotos=buttock or rump) is a quadrilateral area that corresponds to the prominence of the buttocks.

Its boundaries are: (1) ***Medially***, the sacrum and the coccyx, (2) ***Laterally***, the side of the junctional area of abdomen and thigh, (3) ***Superiorly***, the iliac crest and (4) ***Inferiorly***, the deep horizontal furrow of the transverse gluteal fold. It is actually a transitional region between the back of trunk and back of thigh. Though physically it appears to be part of the trunk, functionally it is a region of the lower limb and consists of, in the layman's terms, the buttocks (***regio clunes***) and the hip (***regio coxae***) areas. As indicated by the prominence, this region has several muscles. The ***intergluteal cleft*** (otherwise called the natal cleft) is the midline groove that separates he buttocks from each other. The ***transverse gluteal fold*** (or

contd...

contd .

plainly the gluteal fold or gluteal sulcus) delimits the inferior boundary of the buttocks from the superior part of the thigh. It is a line of adherence of the skin to underlying deep fascia and is the result of the erect posture of man. As the hip extended, and the body assumed the erect posture, the transverse skin crease of the hip joint became prominent and is seen as the transverse gluteal fold

BONY LANDMARKS OF THE GLUTEAL REGION (FIG. 24.1)

These are:

- ***Iliac crest***–its whole length including the anterior superior iliac spine, the tubercle of iliac crest and the posterior superior iliac spine
- ***Ischial tuberosity***
- ***Fourth lumbar*** and ***second sacral*** spines
- Greater and lesser trochanters of femur.

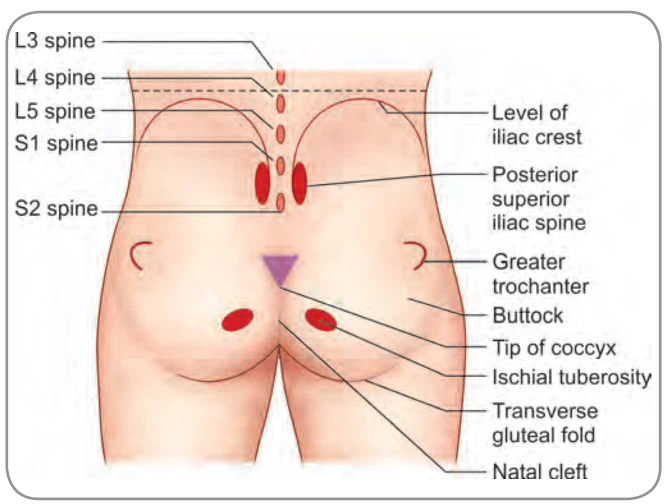


Fig. 24 1: Bony landmarks of the gluteal region

The iliac crest is easily palpated; the tubercle is at the most lateral part of the crest; the anterior superior iliac spine (ASIS) is also easily palpated. The posterior superior iliac spine (PSIS) usually lies in a dimple that is clearly visible. A line joining the highest points of iliac crests of both sides crosses the fourth lumbar spine and thus is a pointer to that spine. ***A line joining the two posterior superior iliac (PSI) spines crosses the second sacral spine***. Extended laterally, the same line crosses the sacroiliac joint. About a hand's breadth below the tubercle of the iliac crest is the greater trochanter, which is the most lateral bony point in the gluteal region. A line drawn at the level of the ischial tuberosity crosses the lesser trochanter and fairly indicates the gap between the quadratus femoris and adductor magnus.

The ischial tuberosity deserves a special mention. The body's weight rests on this tuberosity while sitting. It is a large bony prominence and lies about 5 cm from the midline and about 5 cm above the gluteal fold. It can be felt when the thigh is flexed, by pressing upwards in the region of the medial part of the gluteal fold.

Clinical Correlation

- The line joining the highest points of the iliac crests is important. It cuts through the L4-L5 intervertebral disc and indicates the middle of the lumbar cistern. This is of great help when a lumbar spinal puncture is performed.
- The line joining the skin dimples of posterior superior iliac spines is more visible in women than in men. This line passes through the S2 spine, thus indicating the middle of the sacroiliac joints, the bifurcation of the common iliac arteries and the lowest limit of the dural sac.
- The prominence of the greater trochanter increases when there is atrophy of gluteal muscles and displacement of the trochanter itself.

Bryant's triangle: Otherwise called the iliofemoral triangle; a triangle drawn as under:

- Line A–drawn around the body at the level of anterior superior iliac spines;
- Line B–drawn perpendicular to line A, connecting line A and the greater trochanter of femur;
- Line C–drawn from the trochanter to the anterior superior iliac spine, thus completing the triangle.

The triangle is drawn on both sides and compared. In cases of femoral fractures and hip dislocations, the distance between line A and greater trochanter (measured by the length of line B and is called the supratochanteric distance) is reduced because of an upward displacement of the greater trochanter. The triangle is used as a diagnostic tool in orthopaedics.

Langenbeck's triangle: A triangular area marked by lines connecting the anterior superior iliac spine, surface of greater trochanter and the middle of the neck femur. Any penetrating or deep wound in this triangle will go through the joint.

Bryant's line: Line B of the Bryant's triangle; the line along which the greater trochanter moves in dislocations and fractures.

contd...

Clinical Correlation *contd...*

Inter Cristal line: The line joining the highest points of the iliac crests. This line crosses the intervertebral disc between L4 and L5 vertebrae (and the level of the L4 spine) and indicates the middle of the lumber cistern. This is a very useful landmark while doing a lumbar puncture.

Lanz's line: Commonly called the interspinal line; the horizontal line connecting the two anterior superior iliac spines.

Nelaton's line: The line drawn from the anterior superior iliac spine to the tuberosity of ischium; normally, the greater trochanter lies on this line; in hip dislocations and in femoral fractures, the greater trochanter is felt above this line and so serves as an indicator for diagnosis.

Posterior Iliac spinous line: The line joining the posterior superior iliac spines or as seen on the surface, the line joining the dimples which indicate the posterior superior iliac spines. This line indicates the S2 spine, middle of sacro iliac joints, bifurcation of common iliac arteries and the lowest limit of the dural sac

Roser-Nelaton line: Same as Nelaton's line.

Dissection

With the cadaver in the prone position, study the transverse gluteal fold and the natal cleft. Try to press your fingers in to the medial part of the gluteal fold and feel the ischial tuberosity. Palpate into the floor of the natal cleft to feel the sacrum and coccyx. Between the coccyx and the ischial tuberosity, you may be able to feel a firm structure deeper to gluteus maximus muscle (remember, all these can be felt well in a living individual). It is the sacrotuberous ligament. Try to locate the anterior and posterior superior iliac spines.

Make an incision that is convex upwards, from the upper part of the natal cleft to the lateral aspect of the junction of the back with the gluteal region. Make another incision that is convex obliquely downwards and medially from the medial tip of transverse gluteal fold to the lateral border of the limb at the level of junction of upper and middle thirds of thigh. Reflect the skin flap laterally by making necessary cuts in the midline. Try to reflect the superficial fascia also along with the skin. Since the superficial fascia is thick, dense and packed with fat, it may be difficult to trace the cutaneous nerves; however, several of them can be seen amidst the fat. Try to locate the posterior cutaneous nerve of thigh and follow it upto the thigh.

Clean and define the gluteus maximus muscle. After identifying its attachments, insert your fingers under the inferior margin of the muscle, 3 cm medial to its femoral attachment. Slowly cut the muscle between your fingers and gradually work upwards till the superior border of the muscle. Take care not to injure any nerve or vessel that your fingers may encounter and deviate the line of cut to protect such structures.

Reflect the lateral part of the muscle to its attachment. Reflect the medial part of the muscle, carefully assessing and studying structures which are close to it Then, identify the various structures under cover of Gluteus maximus and study them.

SUPERFICIAL STRUCTURES OF GLUTEAL REGION

Superficial Fascia

The superficial fascia of the gluteal region is filled with fat. Several ***cutaneous nerve twigs*** lie embedded in it. If the region is divided into four quadrants, namely, (1) ***superomedial***, (2) ***superolateral***, (3) ***inferomedial*** and the (4) ***inferolateral***, then the cutaneous nerves can be described by the quadrants in which they are present In the ***superomedial quadrant***, running downwards and laterally from above are the dorsal rami of the L1, L2 and L3 spinal nerves. In the lower part of the same quadrant, running laterally from the sacral area are the dorsal rami of S1, S2 and S3 spinal nerves. In the ***superolateral quadrant***, running downwards and medially from the superolateral angle is the lateral cutaneous branch of subcostal nerve. In the ***inferomedial quadrant***, is the perforating cutaneous nerve. Ascending up from the thigh, in the same quadrant is the gluteal branch of the posterior cutaneous nerve of thigh. In the inferolateral quadrant, running medially across is the branch from lateral cutaneous nerve of thigh.

Deep Fascia

The deep fascia splits to enclose the gluteus maximus muscle. At the superior border of the maximus, it becomes a single sheet and continues upwards to cover the posterior surface of gluteus medius, wherein, it is called the ***gluteal aponeurosis***. On the lateral aspect, the deep fascia merges with iliotibial tract.

MUSCLES OF THE GLUTEAL REGION (TABLE 24.1)

The muscles of the gluteal region are:
- Gluteus maximus
- Gluteus medius
- Gluteus minimus
- Piriformis
- Obturator internus
- Gemelli
- Quadratus femoris
- Obturator externus.

Added Information

The perforating cutaneous nerve is a branch of the sacral plexus. It pierces the sacrotuberous ligament to enter the gluteal region. It supplies the skin of the inferomedial quadrant.

Though all of them share a common muscular compartment, it is customary to classify them into two groups, namely, (1) ***superficial group*** and (2) ***deep group***.

The three large overlapping glutei (***maximus***, ***medius*** and ***minimus***) along with the tensor fasciae latae form the superficial group. All of them have their o igins on the external aspect of the ala of ilium (tensor fasciae latae, though acting along with gluteus maximus, has a greater functional correlation with quadriceps femoris. Hence, it is considered in detail there). The deep group has ***piriformis***, ***two gemelli***, ***obturator internus***, the ***quadratus femoris*** and ***obturator externus***. All of them have their insertions around the intertrochanteric crest of femur

Table 24.1: Muscles of the gluteal region

Muscle	Origin	Insertion	Action	Nerve supply
Gluteus maximus	• External surface of ilium (posterior gluteal line and area behind it including the posterior superior iliac spine) (Fig. 24.2) • Sacrotuberous ligament • Aponeurosis covering erector spinae • Posterior surface of sacrum (lower lateral part) • Posterior surface of coccyx (lateral part)	• Iliotibial tract (Pulls on lateral condyle of tibia) • Gluteal tuberosity of femur (deep fibres)	• Extension of thigh (as in standing up from sitting position or climbing) • When the femur and tibia are fixed as in standing: – Straightens the trunk, after stooping – Maintains upright position of trunk • Through iliotibial tract, it steadies femur on tibia (in standing)	Inferior gluteal nerve (L5, S1, S2)
Gluteus medius	External surface of ilium. The area is bounded by the iliac crest (above), posterior gluteal line (behind), and anterior gluteal line (in front) (Fig. 24.3)	Lateral surface of greater trochanter of femur (on ridge running downward and forward)	Action common for both the muscles: • Both muscles are abductors of the thigh • The minimus and anterior fibres of medius can act as flexors and medial rotators	Superior gluteal nerve (L5, S1)
Gluteus minimus	External surface of ilium, between the anterior and inferior gluteal lines (Fig. 24.4)	Anterior aspect of greater trochanter of femur	• Posterior fibres of medius act as extensors and lateral rotators of thigh • When the femur is fixed (as in standing), the medius and minimus pull their own side	Superior gluteal nerve (L5, S1)

contd...

contd. .

Muscle	Origin	Insertion	Action	Nerve supply
			• of the pelvis downward (by rotating it over the head of the femur). The opposite side of the pelvis is raised	
Piriformis	Anterior (pelvic) surface of sacrum (by three digitations) (Figs 24.5A and B)	Upper border of greater trochanter of femur	Lateral rotator of femur; abductor of flexed thigh	Direct branches from nerves (L5, S1, S2)
Obturator internus	• From pelvic surface of hip bone including the following: – Body, superior ramus, and inferior ramus of pubis – Ramus and body of ischium – Part of ilium • Obturator membrane	• Tendon leaves the pelvis through the lesser sciatic foramen to appear in the gluteal region • Tendon then runs laterally behind the hip joint to reach the medial surface of greater trochanter of femur (in front of trochanteric fossa)	Lateral rotator of femur (more in extended thigh)	Nerve to obturator internus (L5, S1)
Superior gemellus	Posterior aspect of ischial spine	Tendon of obturator internus (thus indirectly into greater trochanter of femur) (Fig. 24.6)	Lateral rotators of femur; Help in abducting the flexed thigh	Nerve to obturator internus (L5, S1)
Inferior gemellus	Uppermost part of ischial tuberosity			Nerve to quadratus femoris (L5, S1)
Quadratus femoris	Lateral border of ischial tuberosity (Fig. 24.7)	Quadrate tubercle (on upper part of trochanteric crest of femur)	Lateral rotator of femur	Nerve to quadrates femoris (L4, L5, S1)
Obturator externus	External surface of anterior part of pelvis including parts of: • Ramus of ischium • Ramus of pubis • Obturator membrane (medial two-thirds)	Tendon runs laterally behind neck of femur to be inserted into trochanteric fossa (on medial surface of greater trochanter)	Lateral rotator of femur	Obturator nerve (L3, L4)

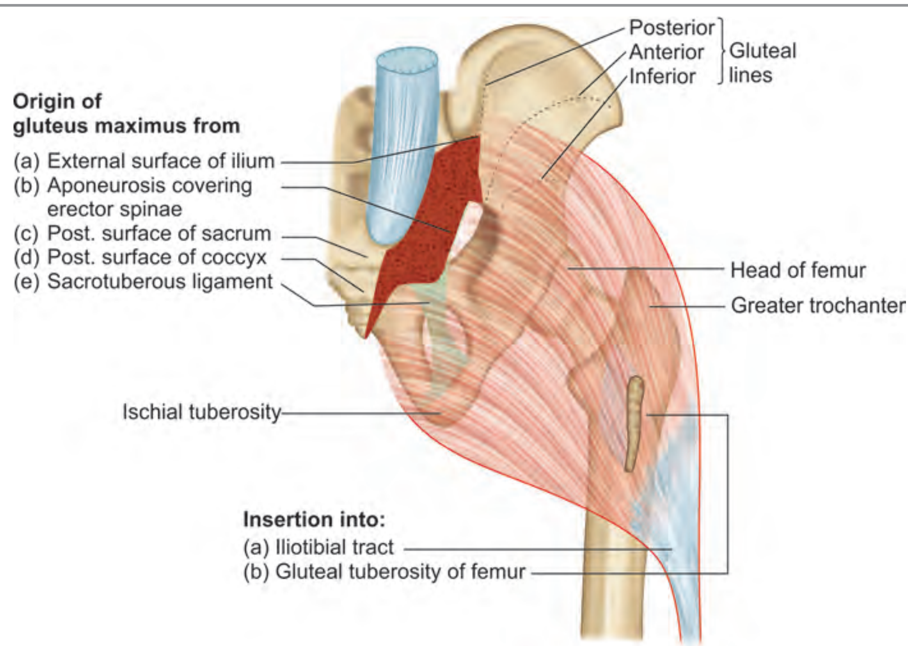


Fig. 24.2: Scheme to show the attachments of the gluteus maximus

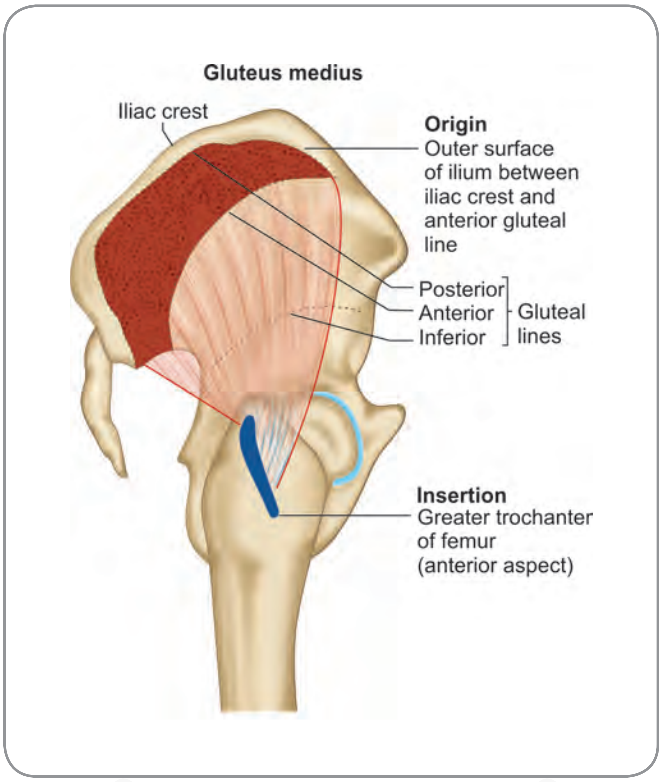


Fig. 24.3: Scheme to show attachments of the gluteus medius. The hip bone and femur are viewed from the lateral side

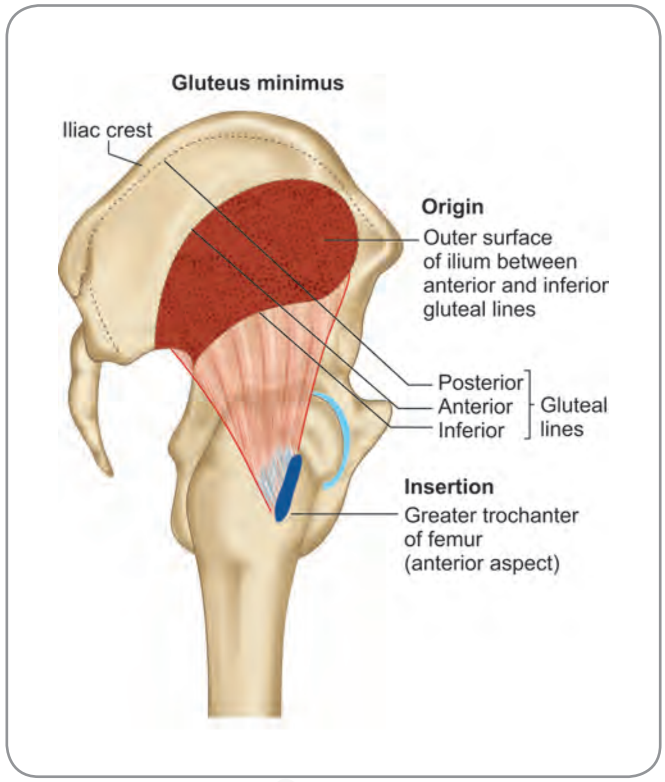
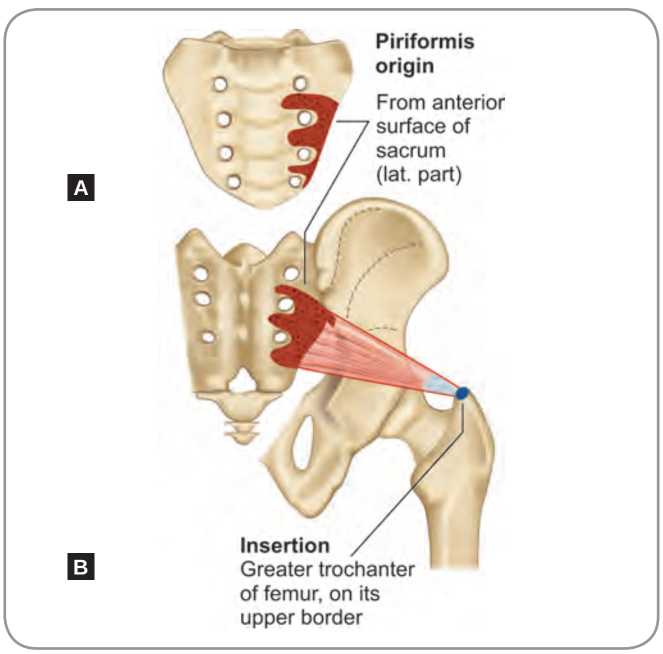


Fig. 24.4: Scheme to show attachments of the gluteus minimus. The hip bone and femur are viewed from the lateral side



Figs 24.5A and B: **A.** Sacrum seen from the front to show the origin of the piriformis **B.** Scheme to show the attachments of the piriformis

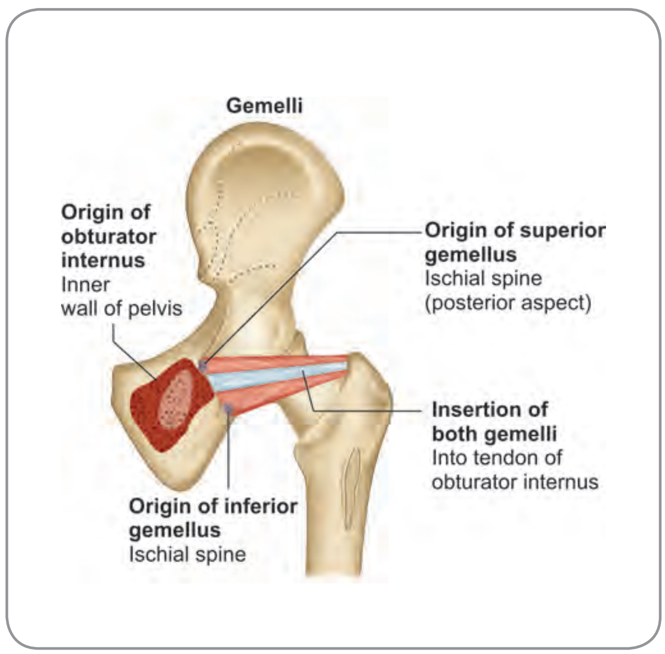


Fig. 24.6: Scheme to show attachments of gemelli

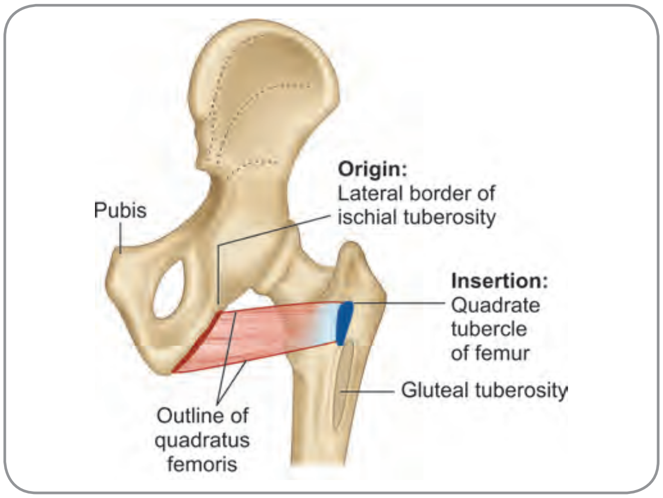


Fig. 24.7: Scheme to show attachments of the quadratus femoris

A List of Structures Under Cover of Gluteus Maximus (Fig. 24.8)

Almost all the structures in the gluteal region are covered by the most superficially placed gluteus maximus muscle. These can be enlisted as follows:
Bones: (1) Ischial spine, (2) Ischial tuberosity, (3) Greater trochanter (of femur), (4) Greater and lesser sciatic foramina.
Ligaments: (1) Sacrotuberous ligament, (2) Sacrospinous ligament.
Muscles: (1) Gluteus medius, (2) Deeper to gluteus medius and gluteus minimus, (3) Piriformis, (4) Obturator internus tendon with the two gemelli, (5) Quadratus femoris, (6) Deeper to quadratus femoris and obturator externus tendon, (7) Hamstrings origin at the ischial tuberosity.
Nerves: (1) Superior gluteal nerve, (2) Inferior gluteal nerve, (3) Sciatic nerve, (4) Nerve to obturator internus, (5) Posterior cutaneous nerve of thigh, (6) Nerve to quadratus femoris, (7) Pudendal nerve
Vessels: (1) Superior gluteal artery and vein, (2) Inferior gluteal artery and vein, (3) Internal pudendal artery (all three are branches of the internal iliac artery), (4) Terminal branch of the medial circumflex femoral artery (that enters this region from the thigh).
Bursae: (1) Ischial or ischiogluteal bursa between gluteus maximus and ischial tuberosity, (2) Gluteofemoral bursa between the gluteus maximus and the vastus lateralis, (3) Trochanteric bursa between gluteus maximus and greater trochanter.

Additional Notes on Gluteus Maximus

- It is the most superficial of the gluteal muscles and is rhomboidal in shape. It is also the largest and the heaviest muscle of the body; its fibres are coarse
- Through a combination of all its actions, it plays a very important role in maintaining the upright position of the body.
- Though it is the strongest extensor of the hip, it is not called to action in standing or normal walking. Its power is utilised under such circumstances where force is necessary. Thus it functions mainly between the flexed and straight positions of the thigh, as when rising from the sitting position, straightening from a forward bend position, in pushing the thigh posteriorly while climbing stairs, walking uphill and running.
- Due to its distal attachment to the gluteal tuberosity of femur and to the iliotibial tract, it acts as a lateral rotator of thigh
- It covers most of the structures of the gluteal region and so, several bones, ligaments, muscles, nerves and vessels lies under cover of it (Fig. 24.8).

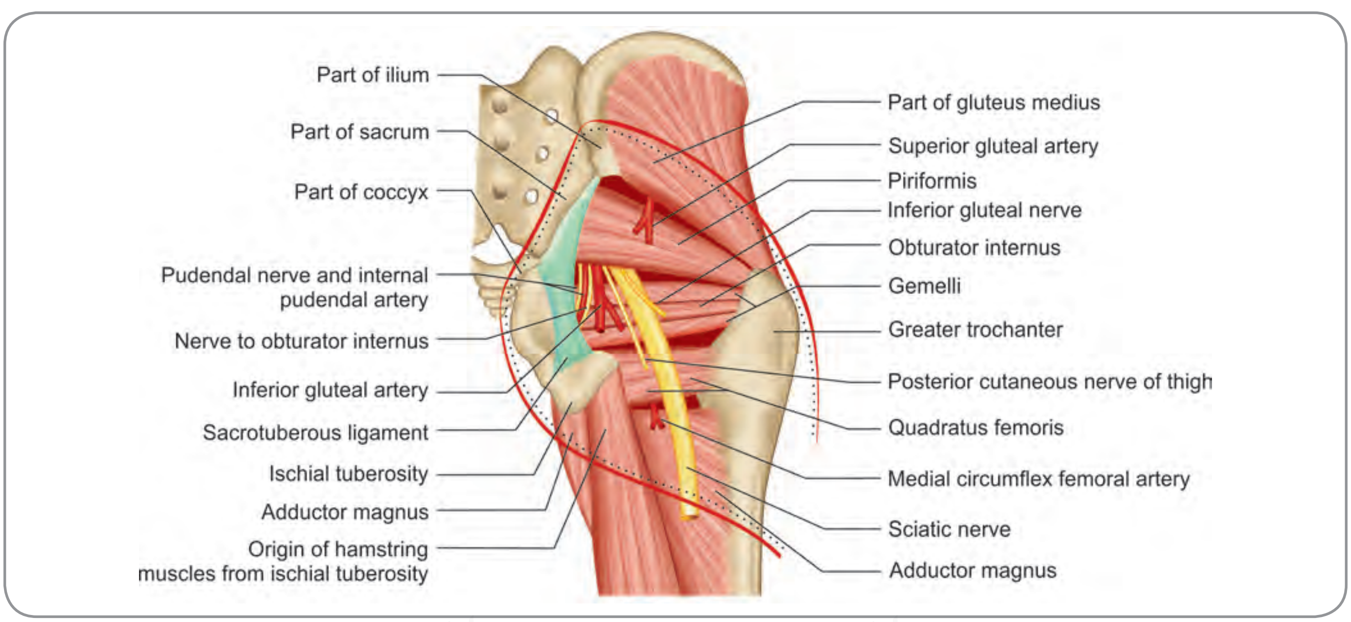


Fig 24.8: Structures under cover of gluteus maximus

- It covers the ischial tuberosity while standing and not while sitting. When the individual sit, there is heavy pressure at the ischial tuberosity (on which one sits) and any structure caught between the tuberosity and the outer surface will have to bear the impact. The fleshy muscle fibres of gluteus maximus cannot survive such an abuse. While sitting, the muscle moves superiorly leaving the tuberosity to be exposed subcutaneously; a thick mass of fibrous tissue intervenes between the tuberosity and the overlying skin, thus reducing the pressure impact.
- It is a specific human muscle, developed and enlarged as a consequence of the erect posture.
- Three-fourths of the muscle gets inserted into the ilio-tibial tract (one-fourth portion formed by the deep fibres of the lower part gets inserted into the gluteal tuberosity); this insertion is extensive and therefore provides the muscle with a powerful hold over the thigh. Through the ilio-tibial tract, gluteus maximus acts to maintain the extension in an extended knee joint.

Additional Notes on Piriformis

- Structures which go to the gluteal region from the pelvis, do so through the greater sciatic foramen. For this reason, the greater sciatic foramen is called the ***doorway to the back***. Piriformis enters the gluteal region by this door and almost fills the doorspace.
- Several vessels and nerves pass through the same foramen both above and below the muscle.
- It is a small pyramidal shaped muscle (Greek.piri= pear, Latin.pirum=pear, form= shape) and due to its coursing from inside the pelvis to the gluteal region, which can be described to have two parts, namely, (1) pelvic part and (2) gluteal part.
- The pelvic part is related anteriorly to (Fig. 24.9):
  - Rectum
  - Branches of sacral plexus.
  - Branches of internal iliac vessels.
  - Posterior aspect of ischium.
- As it emerges out of the greater sciatic foramen and runs in the gluteal region, it is closely related to the posterior aspect of the hip joint.
- At its upper border, the superior gluteal vessels and nerve enter the gluteal region. At the medial part of its lower border, enter the nerve to obturator internus, the internal pudendal vessels and the pudendal nerve; at the lateral part of the lower border, enter the sciatic nerve, the nerve to quadratus femoris, the inferior gluteal vessels and nerve and the posterior cutaneous nerve of thigh. Because of this close association, the piriformis is a guide to all of these structures.
- The line joining the midpoint between the posterior superior iliac spine and the coccyx on the one hand and the top of the greater trochanter on the other, indicates the lower border of piriformis. This line is the ***key line of gluteal region*** and the piriformis, ***the key muscle*** (Fig. 24.9).

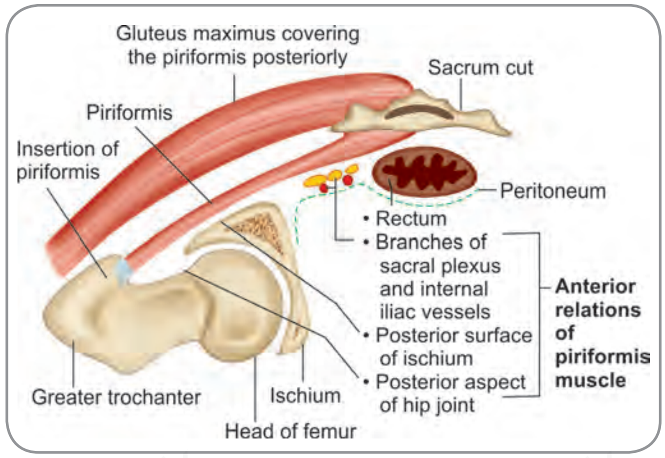


Fig. 24.9: Schematic transverse section through the pelvis (just above the femur) to show relations of the piriformis muscle

Additional Notes on Obturator Internus

- The obturator internus, along with the superior and inferior gemelli (Singular, gemellus; Latin.gemin=twin, geminus= small twin; the twin muscles) forms a tricipital muscle. It arises from the pelvic (inner) surface of the hip bone and from the pelvic surface of the obturator membrane. The fibres of the muscle converge into a tendon, that leaves the pelvis through the lesser sciatic foramen to enter the gluteal region.
- As the tendon runs through the foramen, it takes a 90° turn and continues laterally behind the hip joint to reach its insertion.
- The muscle, on its pelvic surface, is covered by a thick ***obturator fascia***. The levator ani muscle takes origin from this fascia. The part of the fascia below the origin of the levator ani forms the lateral wall of the ***ischiorectal fossa*** and is closely related to the ***pudendal canal*** (through which the pudendal nerve and internal pudendal vessels pass).
- Though the inferior gemellus receives a separate innervation from the nerve to quadratus femoris, it is better to consider the obturator internus and two gemelli together as a single unit of a tricipital muscle on a functional basis. These, three muscles cannot have a separate action and hence are called '***triceps coxae***' (triceps of the hip).

Important Action of the Small Muscles around the Hip Joint

Although, the various small muscles related to the hip joint are described as medial or lateral rotators, their main action

is to stabilise the joint. In performing this action, they have an advantage over ligaments in that they can fix the joint in any position, whereas a ligament can do so only when it is fully stretched. Such muscles are, therefore, sometimes referred to as ***extensible*** or ***adjustable ligaments***.

Additional Notes on Short Lateral Rotators of Thigh

Piriformis, obturator internus (along with the two gemelli), obturator externus and quadratus femoris are collectively called the ***short lateral rotators of the thigh***. Though all of them rotate the thigh laterally, their more important action is to retain the head of femur into the acetabulum.

Clinical Correlation

- ***Trendelenberg sign:*** With the femur fixed (as in standing), the glutei medius and minimus pull the corresponding side of the pelvis downwards by rotating it over the head of the femur. As a result, the opposite side of the pelvis is raised. In this way, the muscles of one side prevent the opposite side of the pelvis from sinking downwards, when the limb of that side is off the ground. In fact the pelvis on the unsupported side is somewhat higher than on the supported side. In paralysis of the medius and minimus, when the individual stands on the limb of the affected side, the unsupported side becomes lower than the supported side. This is referred to as the positive ***Trendelenberg sign***. A positive Trendelenberg sign can also be seen in dislocation of the hip joint or fracture of the neck of the femur.
- ***Falling, lurching and waddling gaits:*** Paralysis of one or more of glutei causes different kinds of disordered gaits. In paralysis of glutei medius and minimus, whi e the affected side is supported and the individual attempts to raise the normal foot (for walking), in order to maintain balance, the trunk is laterally flexed to the affected side (because the line of centre of gravity passes lateral to the hip joint on the supported side). As the individual walks, this causes a 'dip' to one side; it is called the ***dipping*** or ***lurching gait*** or the ***abductor lurch***.
  - Associated changes are also seen. When the pelvis of the unsupported side is at a lower level, the lower limb, in effect, is hanging down and cannot clear the ground while walking. To compensate, the individual leans away from the unsupported side and attempts to lift the leg. This causes a sway called the ***gluteal sway***. The foot may also be raised high, leading to the steppage gait or may be pushed outward leading to the swing out gait.
  - In bilateral paralysis of Glutei medii and minimi, as the individual takes every step, the trunk is flexed from side to side. This is the ***waddling gait***.
  - In paralysis of gluteus maximus, as the individual places a forward step, the trunk is tilted backwards (so as to maintain the line of gravity). This is called the ***falling*** or ***backward lurching gait***.
- ***Intramuscular injections:*** The gluteal region is a common site for intramuscular injections, since the large muscular area provides adequate absorption. While doing so, injections should only be given in the ***upper*** and ***lateral quadrant*** of the gluteal egion (called the dorsal gluteal site), to avoid any injury to the sciatic nerve and other important structures. The most preferred area of injection is a fingers' breadth posteroinferior to the anterior-superior-iliac spine.

contd...

Clinical Correlation *contd...*

- ***Piriformis syndrome:*** This is a condition where the piriformis muscle is hypertrophied at the greater sciatic foramen and compresses the sciatic nerve. Sportspersons whose activities require more use of gluteal muscles (like in cycling and skating) and women are affected.
- ***Bursitis and sores:***
  - The ischiogluteal bursa over the ischial tuberosity may get inflamed. This condition is called ***Weaver's bottom*** or ***ischial bursitis***. It occurs in persons like weavers, tailors and horsemen, who habitually sit on a hard surface. Flexion of thigh or trunk causes pain.
  - Recurrent microtrauma due to repeated stress as in activities like cycling and rowing which causes repetitive hip extension while being seated leads to inflammation of the bursa; this condition is ***ischial bursitis***. It is a friction bursitis resulting from excessive friction between the bursa and the ischial tuberosity. Pain occurs over the area and increases with the movements of gluteus maximus.
  - The ischial tuberosities bear body weight while sitting. In old people, in which tissues have lost some vitality, the pressure can cause discomfort while sitting whereas in people who are paralysed (and cannot change position periodically) pressure on skin can lead to formation of sores.
  - Inflammation of the bursa overlying the greater trochanter (***trochanteric bursitis***) can lead to pain over the trochanter and lateral thigh region. It is caused by repetitive actions like climbing stairs while carrying heavy objects or running up a steep elevation (including a steeply elevated treadmill). This also is a ***friction bursitis***.
- ***Gluteal hernia:*** Rarely, a hernia might occur through the greater sciatic foramen and protrude into the gluteal region, superior to the piriformis.
- ***Sciatic hernia:*** When a hernia occurs through the lesser sciatic foramen, it is termed as ***sciatic hernia***.

ARTERIES OF GLUTEAL REGION (FIGS 24.10 AND 24.11)

The arteries of the gluteal region are:
- Superior gluteal artery
- Inferior gluteal artery
- Internal pudendal artery

The arteries of the gluteal region are branches, either directly or indirectly of the internal iliac artery. The internal iliac artery is a terminal branch of the common iliac artery, and lies within the pelvis. It divides into anterior and posterior trunks, both of which give several further branches.

Superior Gluteal Artery

The ***superior gluteal artery*** is the direct continuation of the posterior trunk of the internal iliac artery. It leaves the

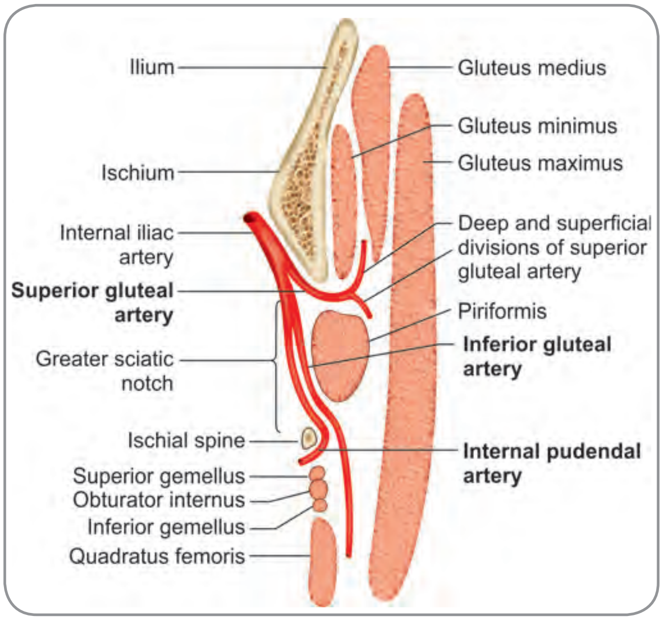


Fig. 24.10: Schematic vertical section of the gluteal region to show the course of some arteries

pelvic cavity by passing through the greater sciatic foramen, superior to the piriformis muscle and immediately divides into the superficial and deep branches. The ***superficial branch*** ramifies deep to the gluteus maximus and supplies it It also send twigs to supply the skin over the proximal part of the muscle. The ***deep branch*** passes upwards over the gluteal surface of the ilium. It further divides into superior and inferior divisions, both of which lie deep to the gluteus medius. The superior division runs along the upper border of the gluteus minimus, while the inferior division crosses the lower part of the same muscle. Both divisions supply the gluteus medius and gluteus minimus, send twigs to the hip joint and finally anastomose with branches of the medial and lateral circumflex femoral arteries and also with branches of inferior gluteal artery. The inferior division also sends a branch to the trochanteric anastomosis.

Inferior Gluteal Artery

The ***inferior gluteal artery*** is a branch of the anterior trunk of the internal iliac artery. It begins within the pelvis, where it lies anterior to the piriformis. It passes through the greater sciatic foramen, below the piriformis to enter the gluteal region (Fig. 24.11). It then descends deep to the gluteus maximus muscle, over the obturator internus (and gemelli) and the quadratus femoris and subsequently extends into the upper part of the thigh. ***Muscular branches*** of the inferior gluteal artery supply the various muscles of the region; one or two ***coccygeal branches*** reach the skin over the coccyx. An ***anastomotic branch*** (Fig. 24.11) takes part in the cruciate anastomosis. The terminal portion of the inferior gluteal artery usually continues as the ***companion artery of the sciatic nerve*** which runs as a slender twig on the surface of the sciatic nerve or its substance

Internal Pudendal Artery

The ***internal pudendal artery*** is a branch of the anterior trunk of the internal iliac artery. The artery passes out of the pelvic cavity through the greater sciatic foramen to enter

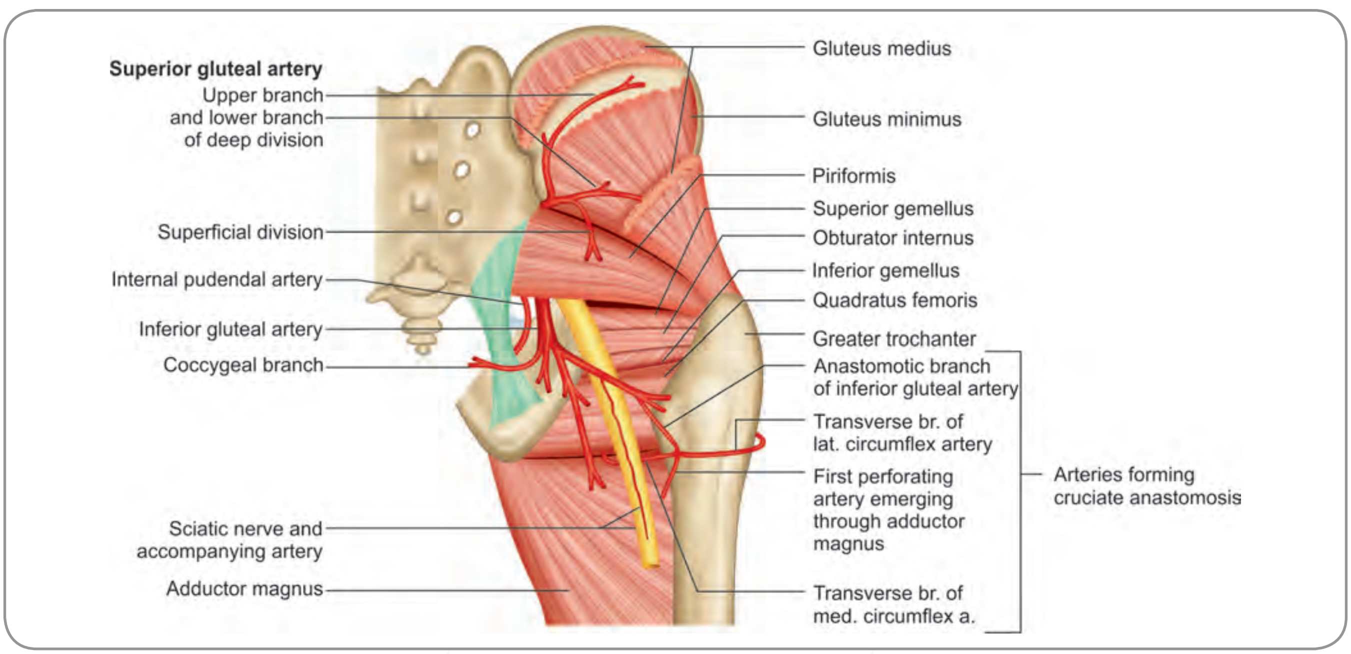


Fig. 24.11: Dissection of the gluteal region showing the arteries of the region

Dissection

For better identification of some of the structures:

- Uncover the ischial tuberosity by reflecting the medial part of the gluteus maximus muscle;
- Detach the gluteus maximus from the sacrotuberous ligament;
- Clean the fascia over piriformis and trace this muscle till the greater trochanter;
- Clean the sciatic nerve and retract it laterally to expose the posterior aspect of acetabulum;
- Identify the ischial spine and sacrotuberous ligament medial to the sciatic nerve and find the PIN structures;
- Deep to the sciatic nerve, make out the obturator internus tendon flanked by the gemelli and inferior to these, the quadratus femoris muscle;
- Separate quadratus femoris from the adductor magnus that is inferior to the former;
- If necessary, remove quadratus femoris to expose lesser trochanter of femur, posterior part of capsule of hip, and tendon of obturator externus;
- In the upper part, clean the superficial surface of gluteus medius;
- Insert your fingers between the gluteus medius and minimus;
- Cut across the gluteus medius to expose the minimus muscle;
- Detach the gluteus minimus from its origin and expose the capsule of hip joint and the tendon of rectus femoris;
- Study all the structures, including vascular anastomoses, thus exposed.

the gluteal region. Here, it lies inferior to the piriformis muscle. It descends across the back of the ischial spine where the pudendal nerve lies medial to it and the nerve to obturator internus lateral to it. It then leaves the gluteal region, along with these two structures, through the lesser sciatic foramen to enter the perineum. ('Pudendum' is external genitalia; Latin.pudere=be ashamed).

Cruciate Anastomosis (Figs 24.11 and 24.12)

This is an arterial anastomosis present in the lower gluteal region (extending into the upper part of the thigh); it is so called because of its cross-like appearance.

The arteries taking part are:

- From above, the descending (anastomotic) branch of the inferior gluteal artery;
- From below, the ascending branch of first perforating artery (a branch of the profunda femoris artery; it pierces the insertions of the adductores brevis and magnus, to reach the posterior aspect and then ascends on the posterior surface of magnus to reach the anastomosis);
- From the medial and lateral sides respectively, the transverse branches of the medial and lateral circumflex femoral arteries (both of which are branches of the profunda femoris artery);

Trochanteric Anastomosis (Fig. 24.13)

This anastomosis is seen in relation to the greater trochanter (trochanteric fossa) of the femur. The arteries taking part are:

- The descending branch of the superior gluteal artery;
- The ascending branches of the medial and lateral circumflex femoral arteries;
- Sometimes a branch of the inferior gluteal artery

Trochanteric anastomosis is the major source of blood supply to the head of femur.

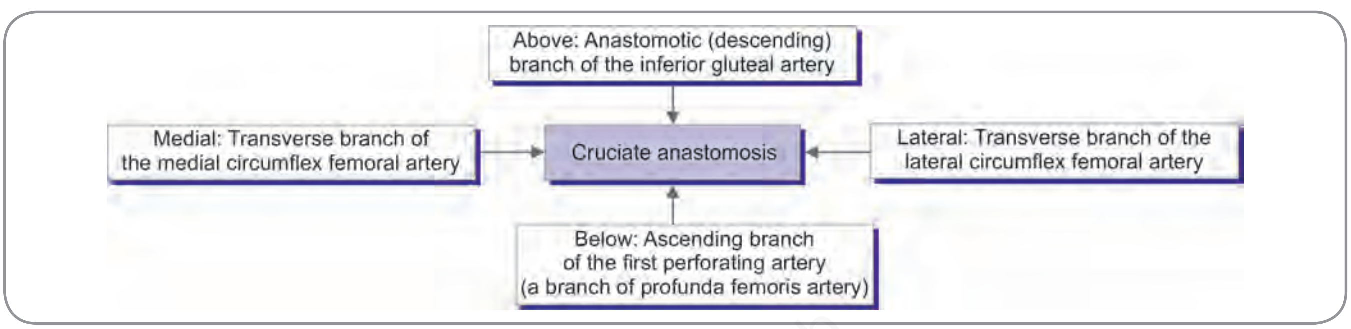


Fig. 24.12: Branches of Cruciate anastomosis

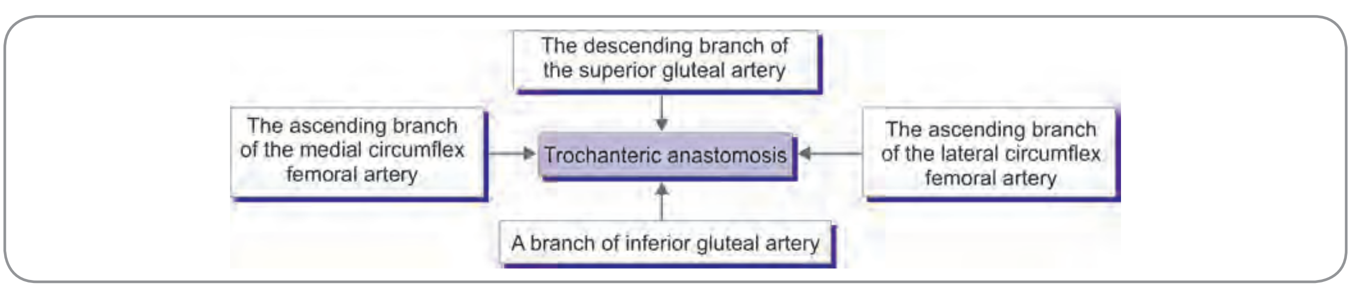


Fig. 24.13: Branches of Trochanteric anastomosis

Veins of Gluteal Region

The superior and inferior veins which drain blood from the gluteal region are tributaries of the internal iliac vein. They run along with their corresponding arteries through the greater sciatic foramen, above and below the piriformis respectively. Tributaries of the gluteal veins communicate with tributaries of femoral vein. Thus a collateral channel between the internal iliac and the external iliac systems is established.

Added Information

- Before leaving the pelvis, the inferior gluteal artery gives out muscular branches to piriformis, levator ani and coccygeus muscles, visceral branches to urinary bladder, seminal vesicle and prostate and twigs to the perirectal pad of fat.
- Before leaving the pelvis, the superior gluteal artery gives out muscular branches to piriformis and obturator internus muscles, nutrient artery to the hip bone and twigs to sacral plexus.

Clinical Correlation

The cruciate anastomosis is an important connection between the external iliac (profunda femoris) and internal iliac (gluteal arteries) territories. When the external iliac artery or the femoral artery proximal to profunda is ligated, the cruciate anastomosis will help in the re-establishment of circulation to the lower limb.

Development

In the foetus, the inferior gluteal artery is the main artery of the posterior compartment of the inferior extremity. It develops from the axis artery of the inferior extremity. However, during development, it regresses in size and diminishes to become the small companion artery to sciatic nerve (otherwise called the ischiadic artery or the arteria comitans nervi ischia dici).

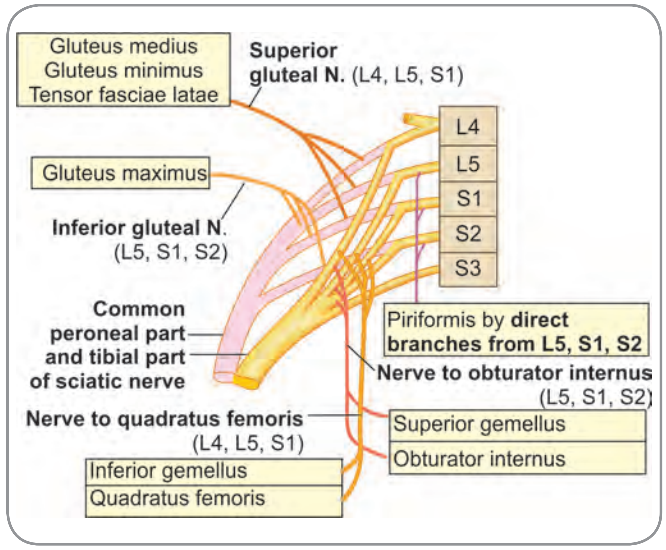


Fig. 24 14: Scheme to show derivation of nerves s pplying muscles in the gluteal region

NERVES OF GLUTEAL REGION (FIG. 24.14)

As much the cutaneous nerves of the gluteal region are called the ***superficial gluteal nerves***, the other nerves of the region are collectively called the ***deep gluteal nerves***. These are the superior and inferior gluteal nerves, the sciatic nerve, nerve to quadratus femoris, posterior cutaneous nerve of thigh, nerve to obturator internus and the pudendal nerve. All these are branches of the sacral plexus and come out of pelvis through the greater sciatic foramen. Except for the superior gluteal nerve, all of them emerge out of the infrapiriform portion of the greater foramen.

Superior Gluteal Nerve

The superior gluteal nerve is derived from the posterior divisions of the anterior rami of L4, L5 and S1 spinal nerves. It arises from the sacral plexus in the pelvis, passes to the gluteal region through the greater sciatic foramen, above the piriformis. Here, it is accompanied by the superior gluteal vessels. Running laterally between the gluteus medius and the gluteus minimus, along with the deep branch of the superior gluteal artery, it divides into superior and inferior branches. The superior branch supplies the gluteus medius, and (occasionally) the gluteus minimus. The inferior branch also supplies these two muscles and ends by supplying the tensor fasciae latae.

Inferior Gluteal Nerve

The inferior gluteal nerve is derived from the posterior divisions of the anterior rami of L5, S1 and S2 spinal nerves. It arises from the sacral plexus in the pelvis, passes to the gluteal region through the greater sciatic foramen, below the piriformis in company with the inferior gluteal vessels and superficial to the sciatic nerve. The branches of the inferior gluteal artery accompany it. It divides into several branches which enter into the deeper surface of gluteus maximus muscle to supply it.

Sciatic Nerve (Fig. 24.15)

The sciatic nerve (Latin.sciaticus-derived from Greek ischiadikos=related to hip) is the largest nerve of the body; it can be called the continuation of the sacral plexus. The rami of the plexus converge at the inferior border of piriformis and thus form the sciatic nerve. The nerve is the most lateral of all the structures emerging through the greater sciatic foramen, inferior to piriformis. As it runs down under cover of gluteus maximus, it lies midway between the greater trochanter and ischial tuberosity.

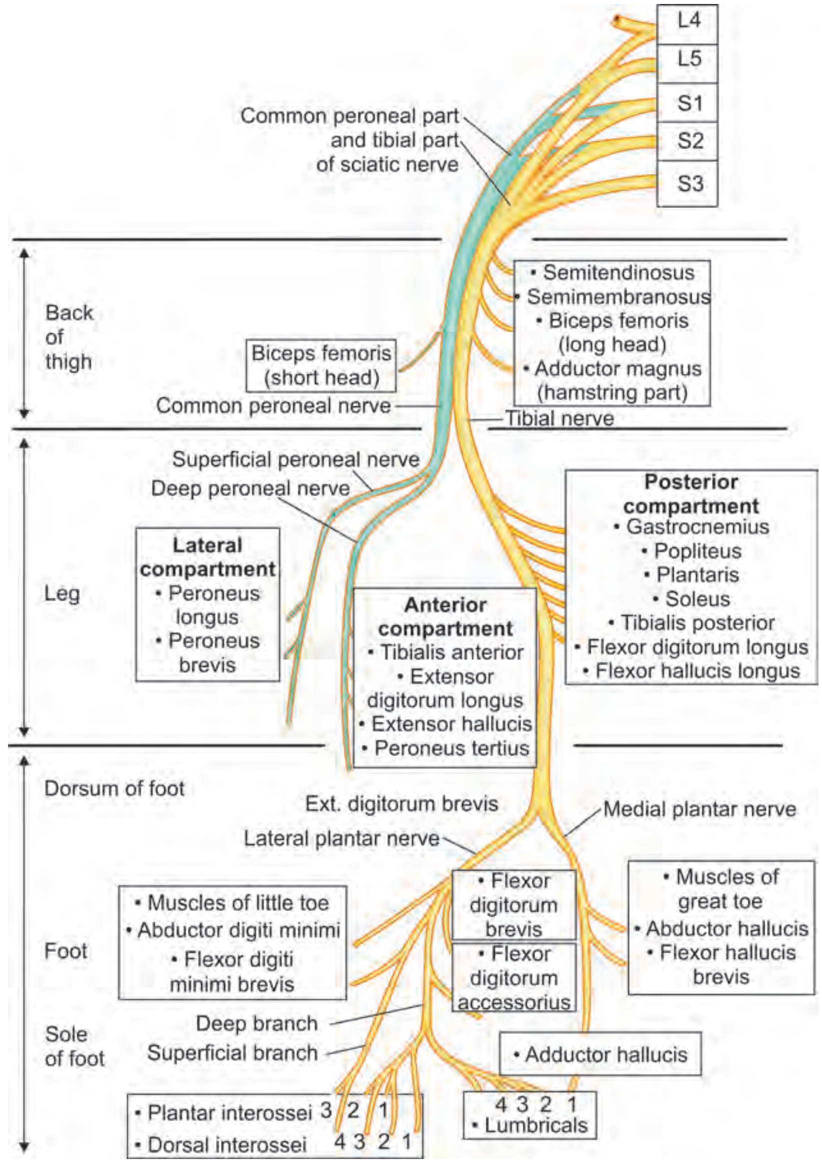


Fig. 24.15: Scheme to show muscles supplied by the sciatic nerve and its ramifications

The nerve lies on the ischium and then passes posterior to obturator internus, quadratus femoris and adductor magnus (in that order from above downwards). It does not supply any structure in the gluteal region and continues down into the back of thigh.

The curvature of the sciatic nerve as it runs in the gluteal region and it becoming superficial in the lower gluteal region make the nerve prone to damage. However, it has a side of danger and a side of safety. Two factors are responsible for this protection. The sciatic nerve is the most lateral in the region. All its branches in the posterior thigh (in cases of high origin, these branches will be given out in the gluteal region itself) are given out on its medial side. So, the medial side of the nerve becomes its side of danger and the lateral, the side of safety

Nerve to Quadratus Femoris

The nerve to quadratus femoris is derived from the anterior divisions of the anterior rami of L4, L5 and S1 spinal nerves and is thus a branch of sacral plexus. It passes from the pelvis to the gluteal region through the greater sciatic foramen, below the piriformis, but deep to the sciatic nerve and the obturator internus. As it descends on the posterior surface of the hip joint, it continues to be deep to superior gemellus, the tendon of the obturator internus, and the inferior gemellus. After giving a branch to the inferior gemellus, it reaches the anterior (or deep) surface of the quadratus femoris and enters the muscle to supply it. While on the posterior aspect of the hip, it may give an articular branch to the joint.

Posterior Cutaneous Nerve of Thigh (PCN)

The posterior cutaneous nerve of thigh, a branch of the sacral plexus and otherwise called the posterior femoral cutaneous nerve, is derived from the anterior and posterior divisions of the anterior rami of S1, S2 and S3 spinal nerves. It passes from the pelvis to the gluteal region through the greater sciatic foramen, below the piriformis. Different from other nerves which are called 'cutaneous', the PCN for most of its course, lies deep to the deep fascia; only the terminal twigs pierce the deep fascia and become truly cutaneous. It is initially medial to sciatic nerve and then becomes superficial to it. Fibres from the posterior divisions of the anterior rami of S1 and S2 form the gluteal branch, that emerges superficial at the lower border of Gluteus maximus and supplies the skin of the inferior part of the gluteal region. The perineal branch is given out in the gluteal region and travels forwards adjacent to the ischial tuberosity to reach the external genitalia. Rest of the nerve continues into the posterior aspect of thigh. Because of its close proximity to the sciatic nerve, the PCN is sometimes referred to as ***'the small sciatic nerve'***.

Nerve to Obturator Internus

The nerve to the obturator internus, another branch of the sacral plexus, is derived from posterior divisions of the anterior rami of L5, S1 and S2 spinal nerves. It passes from the pelvis to the gluteal region through the greater sciatic foramen, below the piriformis. It runs down posterior to the ischial spine and again enters the pelvis by passing through the lesser sciatic foramen. As it lies on the ischial spine, it supplies the superior gemellus. As it re-enters the pelvis, it supplies the obturator internus.

Pudendal Nerve

The pudendal nerve is derived from the anterior divisions of the anterior rami of S2, S3 and S4 spinal nerves. It passes from the pelvis to the gluteal region through the greater sciatic foramen, below the piriformis. It is the most medial of all structures passing through the foramen. It runs over the sacrospinous ligament and re-enters the pelvis through the lesser sciatic foramen. It does not supply any structure in the gluteal region.

PIN Structures

These are structures which have a very short course in the gluteal region. 'PIN' refers to pudendal nerve, internal pudendal vessels and nerve to obturator internus. They are seen over the sacrospinous ligament and the ischial spine. Pudendal nerve (medial most of the three) enters the gluteal region through the greater sciatic foramen, passes over the sacrospinous ligament and enters the perineum through the lesser sciatic foramen. Internal pudendal artery, a branch of the internal iliac artery, has a course parallel to that of the pudendal nerve. It lies immediately lateral to the nerve, crossing over the junction of the sacrospinous ligament and the ischial spine.

contd...

contd...

The artery similar to the pudendal nerve, supplies structures of the external genitalia and perineum and does not supply any structure in the gluteal region. It may be accompanied by a small vein. Lying parallel but still lateral is the nerve to obturator internus. It runs over the ischial spine and supplies the superior gemellus at this level. After entering the perineum through the lesser sciatic foramen, it supplies the obturator internus. Collectively, these structures are called the PIN structures over ischial spine in the gluteal region. However, this mnemonic should not be confused with the anagram 'PIN PINS' used to denote structures passing through the greater sciatic foramen below piriformis–these are posterior cutaneous nerve of thigh inferior gluteal vessels and nerve, nerve to quadratus femoris, pudendal nerve Internal pudendal vessels, nerve to obturator internus and sciatic nerve. It should be noted that the earlier marked structures are very much part of the whole group. It is preferable not to use mnemonics or shortened terms to avoid such confusions.

BACK OF THIGH

Back of thigh or posterior thigh is the region on the posterior aspect of thigh that extends from the lower border of gluteus maximus to the upper limit of popliteal fossa. Vessels and nerves of the back of the thigh, mostly continue down from the gluteal region.

FASCIAE OF THE BACK OF THIGH

The superficial fascia has no special feature. The deep fascia deserves a special mention. It is composed of circularly disposed fibres which are not only densely packed, but are very strong. Closer to the lower end of posterior thigh, the fascia functions like a virtual retinaculum, restraining the tendons of hamstrings from falling off.

CONTENTS OF THE BACK OF THIGH

The contents of the back of thigh are:

- The Hamstring muscles – Semitendinosus, Semimembranosus, Long Head of Biceps femoris;
- Short head of Biceps femoris (not a hamstring);
- Ischial head of adductor magnus;
- The Sciatic nerve;
- The posterior cutaneous nerve of thigh;
- Vessels.

MUSCLES OF THE BACK OF THIGH

The muscles of the back of thigh (otherwise called the posterior femoral muscles) are fairly large, bulky muscles. Of the four, three are grouped together as the 'Hamstrings' These are the Semitendinosus, Semimembranosus and

Table 24.2: Muscles of the back of thigh

	Semitendinosus (Fig. 24.16)	Semimembranosus (Fig. 24.17)	Biceps Femoris (Fig. 24.18)
Origin	Upper medial part of ischial tuberosity	Upper lateral part of ischial tuberosity	Long head from: Upper medial part of ischial tuberosity • Sacrotuberous ligament. Short head from linea aspera of femur
Insertion	Upper part of medial surface of tibia (behind sartorius, below and behind gracilis)	Medial condyle of tibia	Both heads end in a common tendon that is attached to the head of the fibula.
Nerve supply	Sciatic nerve (tibial part) (L5, S1, 2)	Sciatic nerve (tibial part) (L5, S1 2)	Long head by sciatic nerve, tibial part (L5, S1, S2, S3) Short head by peroneal part of sciatic nerve (L5, S1, 2)
Action	These are common to all hamstring muscles. • Flexion of leg at knee joint (when pelvis is fixed) • When the knee is fixed (as in standing) the ischial tuberosity is pulled downwards. This is useful in: – Preventing the pelvis from rolling forwards on the head of the femur – Straightening the trunk after bending forwards (extension of hip joint)		

the long head of Biceps femoris (Table 24.2). If the femur is imagined to be an arch (due to its convexity forwards), then these muscles, extending from the ischial tuberosity to the upper end of leg, form strings (strings of the ham, and thus, hamstrings; 'ham' is back of thigh) to the arch. Therefore, it is necessary for the 'hamstrings' to have the following features:

- Origin from or proximal attachment to ischial tuberosity;
- Insertion or distal attachment to one of the bones of the leg;
- Nerve supply by the medial division of the Sciatic nerve;

Thus, they span the whole length of femur but have no attachment to it. They also span two important joints (the hip and the knee). Their actions on the hip (extension) and on the knee (flexion) are also considered as a features of a hamstring muscle. The short head of biceps and the adductor magnus do not qualify to be a 'complete' hamstrings because they do not fulfil all the definition criteria.

The hamstrings can be conveniently described to extend the hip and flex the knee joints. Both actions cannot be completely done simultaneously. It is not possible to extend the knee fully when the hip is fully flexed. These muscles are active in extension of thigh under all situations. They are also the hip extensors in normal walking.

The tendons of Sartorius, Gracilis and Semitendinosus form the 'pes anserinus' at their insertions.

Additional Notes on Semitendinosus

The muscle is so called because its lower half is tendinous. On reaching the knee, the tendon of the semitendinosus runs forwards across the tibial collateral ligament to reach its insertion.

Clinical Correlation

- In injury to the superior gluteal nerve, the gluteus medius and minimus are paralysed. The Trendelenberg test is positive.
- Intramuscular injections, wrongly administered in the supero-medial quadrant can damage the superior gluteal nerve.
- Sciatic nerve is anasthetised (blocked) by injecting the anaesthetic agent a few cms below the midpoint of the upper border of the greater trochanter and the posterior superior iliac spine

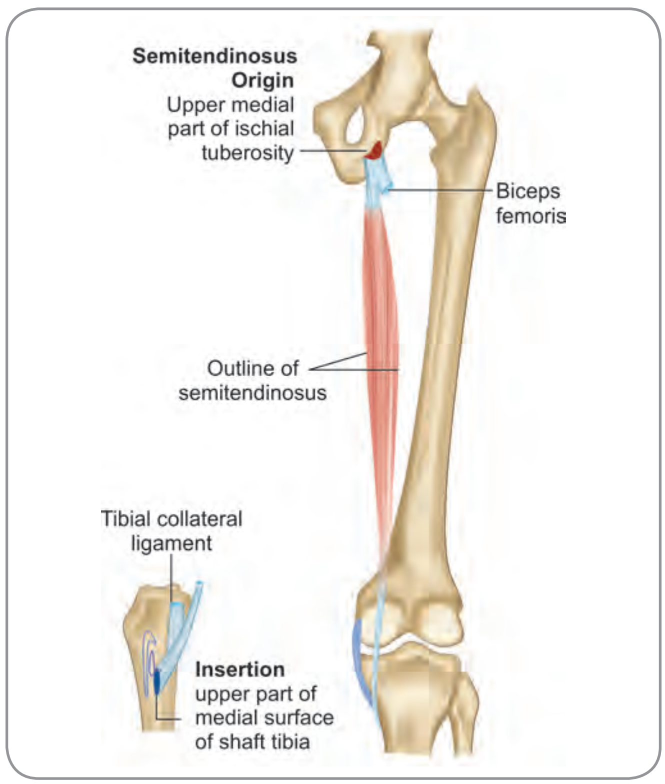


Fig. 24.16: Scheme to show attachments of the semitendinosus muscle

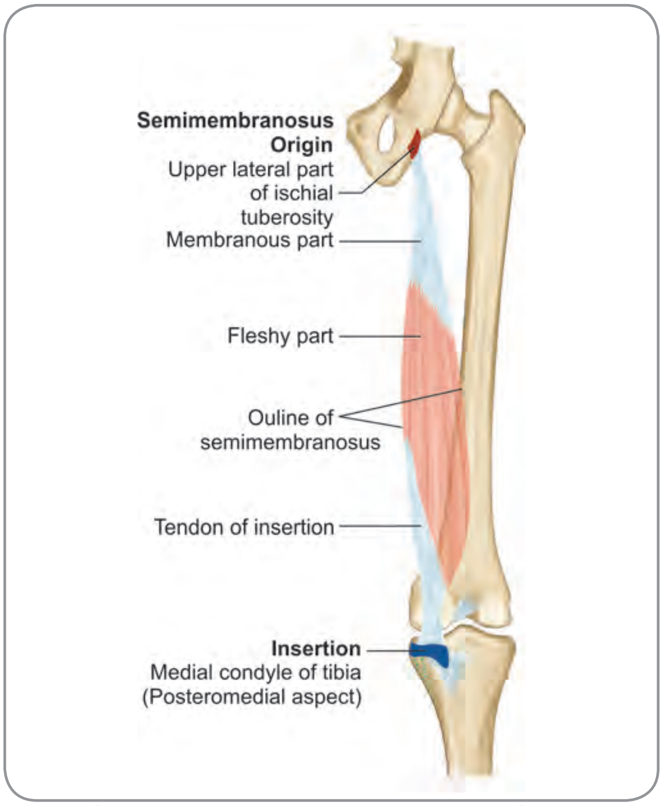


Fig. 24.17: Scheme to show attachments of the semimembranosus muscle

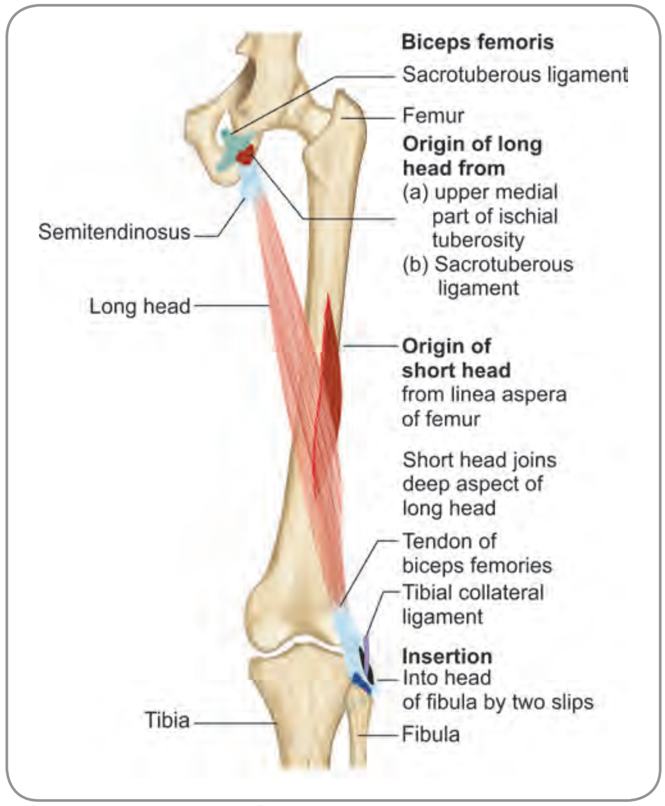


Fig. 24.18: Scheme to show attachments of the biceps femoris muscle

Additional Notes on Semimembranosus

The muscle is so called because its upper part is membranous. The membranous part of the muscle lies under the cover of the biceps femoris. The fleshy fibres of the muscle end in a tendon which is placed along the medial edge of the muscle. As the tendon divides distally into four parts, there are four insertions. The main and direct insertion is into the posterior aspect of the medial condyle of the tibia. Secondly, some fibres become continuous with the fascia covering the popliteus. Thirdly, some fibres pass upwards and laterally over the joint capsule of the knee and get attached to the lateral condyle of the femur. This set of fibres reinforces the joint capsule and forms the oblique popliteal ligament. Fourthly, some fibres descend to be attached to the medial margin of the shaft of the tibia behind the tibial collateral ligament.

Additional Notes on Medial Hamstrings

The semitendinosus and semimembranosus together are called the '***medial hamstrings***'. When the knee is flexed to about 90 degrees, contraction of medial hamstrings produces a small amount of medial rotation of the leg. During of extension of hip, the medial hamstrings is not as active as the Biceps femoris.

Additional Notes on Biceps Femoris

The origin of the short head from the linea aspera lies between the insertion of the adductor magnus, medially, and the origin of the vastus lateralis, laterally. The short head ends by joining the deep aspect of the long head. The long head is otherwise called the '***lateral hamstring***'. The two heads end in a common tendon which is inserted into the head of the fibula. Just above the insertion, the tendon splits into two parts that embrace the fibular collateral ligament. When the knee is flexed, the Biceps femoris produces a limited lateral rotation of the leg.

Biceps is a composite muscle. The long head, supplied by the tibial division of the sciatic nerve, developmentally belongs to the front of the embryonic limb. The short head, supplied by the peroneal division, belongs to the back.

Clinical Correlation

In athletes, the hamstrings are liable to generate excessive strain (because extension of hip and flexion of knee are essential for running and all other associated movements). The attachment of the muscles at the ischial tuberosity may be torn or avulsed leading to a very painful condition called '***pulled hamstrings***'.

VESSELS OF THE BACK OF THIGH

The perforating arteries and the anastomosis that they form are the important vascular structures of the back of the thigh.

Four perforating arteries are usually present. The upper three are branches of the profunda femoris artery, whereas the fourth is the terminal continuation of the profunda itself. Arising in the anterior compartment of the thigh, these arteries run a transverse course to pierce the aponeurotic insertion of adductor magnus into the linea aspera of the femur. Thus, they reach the posterior compartment. In the posterior compartment, they give out muscular branches to the hamstring muscles. Then each perforating artery gives out an ascending and a descending branch. The ascending branch anastomoses with the descending branch of the preceding perforator (or, in the case of the first perforator, with the descending branch of inferior gluteal artery); the descending branch anastomoses with the ascending branch of the succeeding perforator (or, in the case of the fourth perforator, with the ascending branch of the popliteal artery).

A continuous and anastomotic arterial chain is thus established and this chain extends from the gluteal to the popliteal region. The perforators is usually terminate by piercing the lateral intermuscular septum and ending in the substance of vastus lateralis.

Perforating veins accompany their counterpart arteries and end in profunda vein. They too, communicate superiorly with the inferior gluteal vein and inferiorly with the popliteal vein.

NERVES OF THE BACK OF THIGH

Two nerves are seen coursing through the back of the thigh. These are the sciatic nerve and the posterior cutaneous nerve of the thigh.

The sciatic nerve, from the gluteal region, runs down the posterior thigh. It is in reality two nerves in one common connective sheath. The two nerves are the medially placed tibial nerve and the laterally placed common peroneal nerve (Greek.perone= a nail, Latin.fibulare=a pin).

As it runs in the posterior compartment, the nerve is crossed by the Biceps femoris muscle. Still lying deep to biceps femoris and at the junction of the middle third of the thigh with the lower third, the two divisions separate off. The tibial and the common peroneal nerves are otherwise

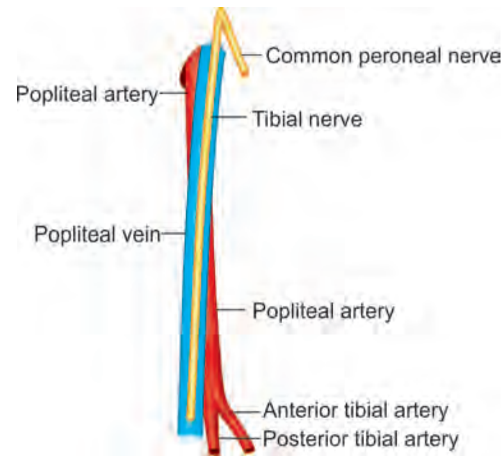


Fig. 24.19: Relationship of popliteal artery to popliteal vein and t bial nerve

called the ***medial*** and ***lateral popliteal nerves***. The separation can be higher or lower. It runs midway between the ischial tuberosity and the greater trochanter. Muscular branches to the hamstrings arise from the medial side of the nerve. Branch to the short head of Biceps femoris arises from the lateral side of the nerve, wherein the fibres of the common peroneal component contribute. From above downwards, the nerve lies on the dorsal surface of ischium, the tricipital structures of Obturator internus and two gemelli, Quadratus femoris and Adductor magnus. The inferior gemellus and the Quadratus femoris intervene between the sciatic nerve and the hip joint.

The posterior cutaneous nerve of thigh, as it continues down from the gluteal area, gives cutaneous branches to the posterior thigh. These come out on both sides of the nerve. When the nerve reaches the upper apex of popliteal fossa, it pierces the deep fascia to reach the skin; it ends by supplying the skin of the calf (Fig. 24.19).

Clinical Correlation

The sciatic nerve runs down on the quadratus femoris and the adductor magnus. Between these two muscles, for a very short distance, the nerve lies on the femur. This is considered as a vulnerable point. If a person sits on the edge of a hard surface, the nerve may be compressed between the surface and the femur. Numbness of the lower limb occurs. The condition is called '***sleeping foot***' and the sensations come back on resuming correct posture.

Multiple Choice Questions

1. Gluteal aponeurosis:
   a. Covers the posterior surface of gluteus maximus
   b. Covers the posterior surface of gluteus medius
   c. Splits to enclose gluteus maximus
   d. Is the superficial fascia of gluteal region
2. The superficial group of muscles of the gluteal region are:
   a. The three glutei muscles
   b. The three glutei and tensor fascia lata
   c. The three glutei and piriformis
   d. The three glutei and obturator internus
3. Gluteus maximus acts as a lateral rotator of thigh:
   a. Due to its most superficial position in the gluteal region
   b. Due to its distal attachment to gluteal tuberosity and iliotibial tract
   c. Due to its coarse fibres
   d. Due to its strong extension action
4. The gluteal region is the preferred site for intramuscular injections:
   a. Because of the large muscular area for absorption
   b. Because of special absorptive properties
   c. Because of several small muscles underlying the large muscles
   d. Because of proximity of ne ves so that the drug can be absorbed easily
5. Companion artery of sciatic nerve:
   a. Is a branch of superior gluteal artery
   b. Is the continuation of inferior gluteal artery
   c. Is a branch of internal iliac artery
   d. Is the continuation of internal pudenal artery

ANSWERS

1. b **2.** b **3.** b **4.** a **5.** b

Clinical Problem-solving

Case Study 1: A 36-year-old man walked into the clinic of a physician. He had a dip to the left when he walked; as he attempted to lift his right leg he swayed and leaned more to the left side.

- What name would you give to the gait he had with a dip to the left side?
- What condition did the man have? And which side was affected?
- Why did he sway to the left side while lifting the right leg?

Case Study 2: A 42-year-old woman developed numbness in her left lower limb. After a few days, the numbness was replaced by pins and needles which then developed into unbearable pain. She also developed difficulty in movements of knee and leg. All these symptoms made the woman feel miserable as she could not do her regular exercises and practice for her ensuing sprint competitions. There was no visible swelling anywhere.

- What do you think was she suffering from? Is a there a possibility of a muscle involvement?
- Which nerve was involved? And why did the nerve get involved?
- Why is it important to know that the patient was a sportsperson and a woman?

(For solutions see Appendix).

Chapter 25

Popliteal Fossa

Frequently Asked Questions

- Discuss the extent, boundaries and contents of popliteal fossa.
- Describe the course and relations of popliteal artery. Add a note on its branches.
- Write notes on the arterial anastomosis around the knee joint.

POPLITEAL FOSSA

The popliteal fossa (Greek.poples=back of knee) is a potential, fat-filled rhomboidal (like a diamond) space present at the back of the knee. The fossa can be described to have upper and lower boundaries, a floor, and a roof. Due to its rhomboid shape, the boundaries are sloping and so there are the superomedial, superolateral, inferomedial and inferolateral boundaries.

Boundaries of popliteal fossa (Fig. 25.1):
- ***Superomedially:*** Semitendinosus and semimembranosus
- ***Superolaterally:*** Biceps femoris
- ***Inferomedially:*** Medial head of gastrocnemius
- ***Inferolaterally:*** Lateral head of gastrocnemius and plantaris.

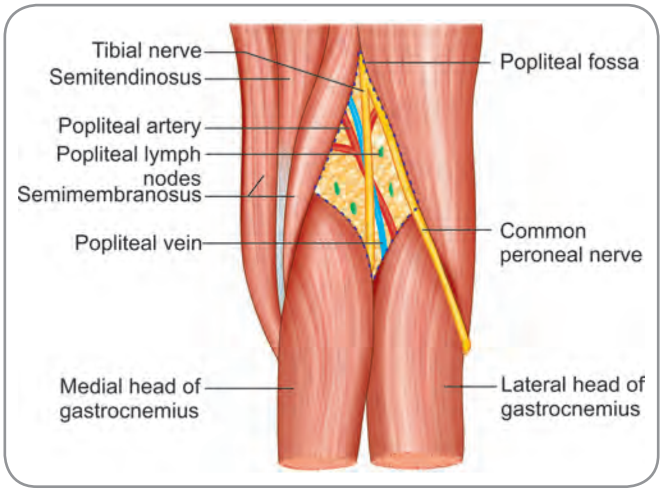


Fig. 25.1: Popliteal fossa—boundaries and contents

Roof (Fig. 25.3)

The roof (also the posterior wall) is formed by the deep fascia (otherwise called the popliteal fascia), the superficial fascia and the skin over the fossa. In the superficial fascia are the terminal part of the small saphenous vein and the three cutaneous nerves namely; (1) the posterior cutaneous nerve, (2) the medial cutaneous nerve of leg and (3) the lateral cutaneous nerve of leg.

Floor

The floor (also the anterior wall) consists of, from above downwards, the popliteal surface of femur, capsule of knee joint (including the oblique popliteal ligament), and fascia over the popliteus muscle [with the popliteus muscle lying deeper to it (Figs 25.2 and 25.4)].

Contents

The contents of the fossa are (Fig. 25.1):

- ***The popliteal artery:*** It is a continuation of the femoral artery and runs vertically down the middle of the fossa. It gives off a number of branches
- ***The popliteal vein:*** It partially overlaps the popliteal artery and receives several tributaries
- ***The tibial nerve:*** It lies superficial to the popliteal vein, it is a terminal branch of the sciatic nerve. In the fossa,

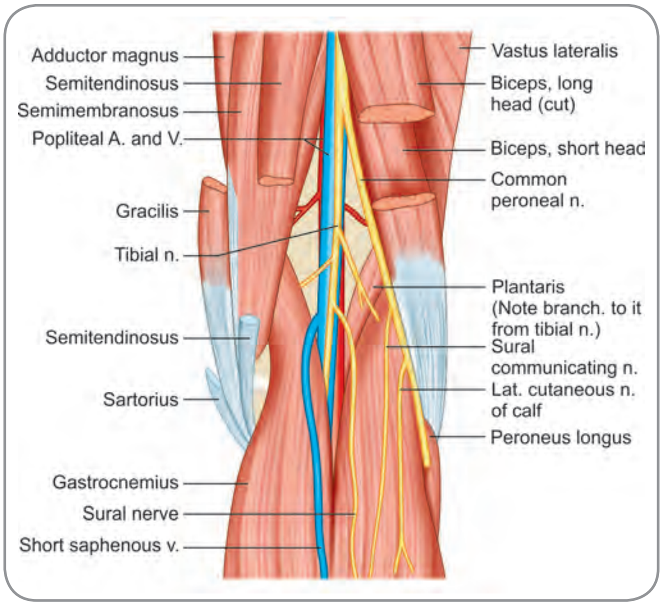


Fig. 25.2: Popliteal fossa showing deeper level than shown in Figure 25.1

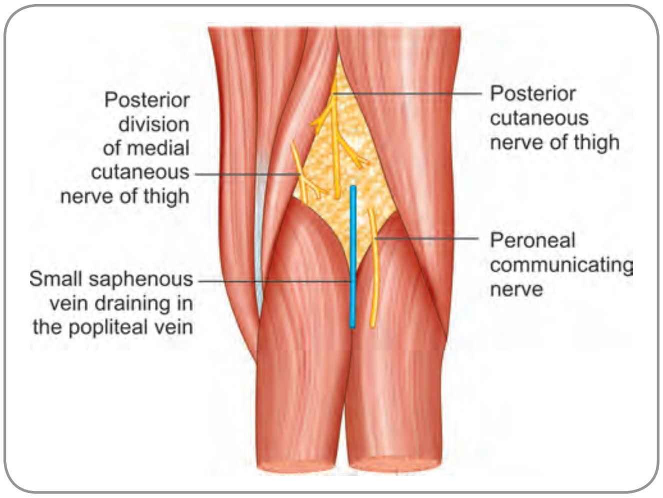


Fig 25.3: Structures in the roof of popliteal fossa

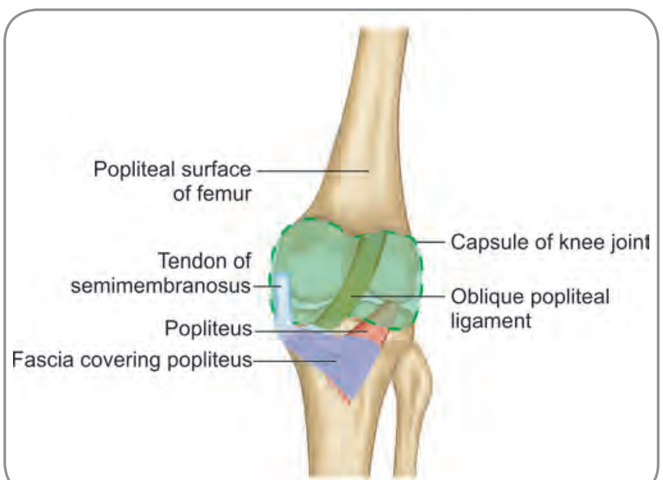


Fig. 25.4: Structures forming the floor of popliteal fossa

it gives muscular branches to (a) both heads of the gastrocnemius, (b) the plantaris, (c) the popliteus, (d) the soleus and (e) genicular branches to the knee joint

- ***The common peroneal nerve*:** It is another terminal branch of the sciatic nerve. It runs downwards and laterally along the biceps femoris. In the fossa, it gives off some branches, these are; (a) the sural communicating nerve (that joins the sural nerve), (b) the lateral cutaneous nerve of the calf (that supplies skin on the lateral side of the back of the leg) and (c) genicular branches to the knee joint
- The popliteal group of lymph nodes and lymphatics
- The popliteal pad of fat.

Dissection

Though it is preferable to dissect and study the popliteal fossa before dissecting the back of thigh or back of leg it may not always be possible. If one of the latter mentioned regions is already dissected, extend the necessary incision(s) to the required level to expose the popliteal fossa .

Direct exposure of popliteal fossa: With the cadaver in prone position, the lower limb is stretched well.

Mark a level about 2 cm above the superior border of patella. Mark another level at the inferior limit of tibial tuberosity. Make horizontal incisions at both these levels on the posterior aspect of knee. The medial and lateral extents of these incisions should stop where the posterior aspect turns to become medial and lateral aspects respectively Make a longitudinal incision connecting the two horizontal incisions, on the midline of the region.

Using caution, reflect the medial and lateral flaps of skin.

POPLITEAL VESSELS

POPLITEAL ARTERY

Course and Relations (Fig. 25.5)

The ***popliteal artery*** begins at the junction of the middle- and lower-thirds of the thigh, being continuous with the lower-end of the femoral artery through the opening in the adductor magnus. It lies deep in the popliteal fossa, on the back of the knee joint. It runs downwards and laterally, lying successively on the popliteal surface of the femur, the capsule of the knee joint and the popliteus muscle. The artery ends at the lower border of the popliteus by dividing into the ***anterior*** and ***posterior tibial arteries***.

Superficially (i.e., posteriorly) the artery is partly overlapped by muscles forming the medial margin of the popliteal fossa. These are the semimembranosus (over the upper part) and the medial head of the gastrocnemius (over the lower part). It is crossed by the popliteal vein and the tibial nerve; the vein intervenes between the artery and the nerve More superficially, it is covered by skin and fascia.

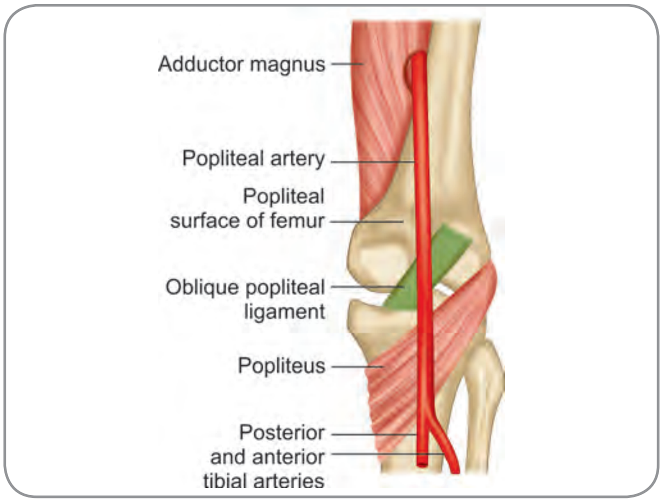


Fig. 25.5: Diagram to show the course of the popliteal artery

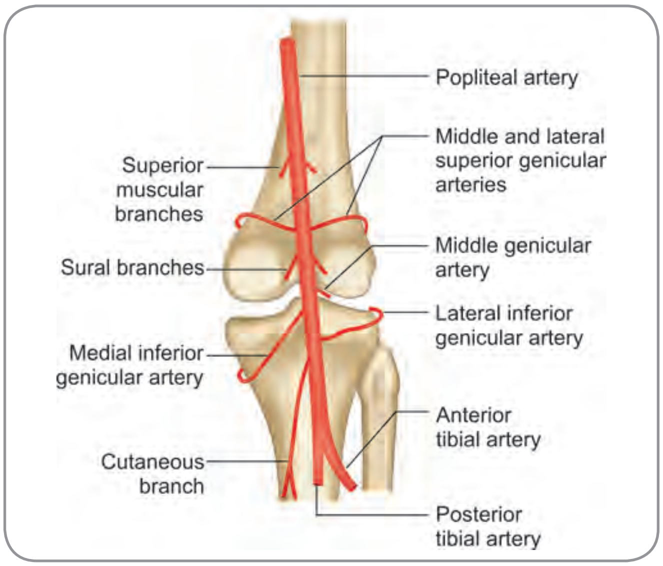


Fig. 25.6: Branches of popliteal artery

Branches (Fig. 25.6)

The popliteal artery gives out genicular branches which form a network of vessels around the knee joint, called the peri articular genicular anastomosis. These branches are the superior medial, superior lateral, inferior medial and inferior lateral genicular arteries. The middle genicular artery pierces the oblique popliteal ligament on the posterior aspect of knee joint to supply the intra-articular structures. The muscular branches of the popliteal artery are those to the hamstrings (branches supplying hamstrings are called the ***superior muscular branches***), the gastrocnemius, the soleus and the plantaris (branches to these muscles are called the ***sural arteries***) muscles.

Surface Anatomy

A line joining the following three points will indicate the popliteal artery on the surface; (1) at the junction of the middle and the

contd...

contd...

lower thirds of the thigh, on the back of the limb, 2.5 cm medial to the midline, (2) on the midline right at the back of knee, (3) on the midline, at the level of tibial tuberosity on the back of leg. The line joining the first two points should be concave medially in its upper part; then the line runs vertically down.

Development

The popliteal artery develops from two sources. Proximal part of it till the level of popliteus muscle is part of the axis artery of lower limb. Distal part of it from popliteus to its division is from the new vessel that also gives rise to the femoral artery in the upper portion

POPLITEAL VEIN

In close association with the artery is the popliteal vein. It is formed at the inferior border of the Popliteus by the union of venae comitantes accompanying the anterior and posterior tibial arteries. The vein is posterior (i.e., superficial) to the artery. At the upper end of the artery, the vein is lateral; it gradually crosses the artery so that it comes to lie medial to the lower-end of the artery. Throughout this triple relationship to the artery (lateral—posterior—medial), the popliteal vein separates the tibial nerve from the artery. The vein has several valves. Superiorly, it traverses the adductor hiatus to become the femoral vein. The tributaries of the vein correspond to the branches of the popliteal artery. In addition, it receives the small saphenous vein which enters into it after piercing the deep fascia.

Dissection

As you reflect the skin flaps, try not to cut or injure the cutaneous nerves and the terminal portion of the small saphenous vein in the superficial fascia. Clean them and protect them intact.

The deep fascia may be laden with fat. Remove remnants of the fascia and fat piece meal, so as not to injure deeper structures. Once the deep fascia is cleaned up, underlying muscles and nerves come into view. Define, by blunt dissection the medial and lateral heads of gastrocnemius; also define the lower parts of the hamstring muscles. The nerves can serve as guides to muscles. Use your fingers to define the tibial nerve which is usually seen as a thick rounded cord, running through the middle of popliteal fossa. Follow the nerve superiorly to reach the division of sciatic nerve into the tibial and common peroneal components. The usual level of division is at the superior border of popliteal fossa. From this point, follow the common peroneal nerve. It runs parallel to the superolateral border of popliteal fossa and thus serves a guide to the biceps femoris muscle. It can also be traced to pass superficial to the lateral head of gastrocnemius and plantaris.

Trace the tibial nerve inferiorly. At the inferior angle of popliteal fossa, the nerve passes deep to gastrocnemial heads and plantaris.

contd...

Dissection *contd...*

Once the various muscles forming the borders of the popliteal fossa are identified, pull them apart for about 3 to 5 cm. Deeper structures can now be seen. Deep to the tibial nerve, the popliteal vessels can be made out. Clean the connective tissue sheath enclosing the vessels and nip open if necessary. Study the vessels after separating the artery and the vein with a blunt probe.

With utmost care, retract the vessels to see the various genicular branches arising out of the popliteal artery. Popliteus muscle can also be seen the same way. Muscular branches of the tibial nerve to both heads of gastrocnemius and plantaris can be seen entering the muscles as they form borders of PF. If adequate retraction is possible, nerve to politeus can be seen; t runs on the posterior surface of the muscle and turns around its distal border.

ANASTOMOSIS AROUND THE KNEE JOINT (FIG. 25.7)

The knee is surrounded by a complex arterial anastomosis. Apart from the genicular branches of the popliteal artery, some other arteries also contribute to this anastomosis. These are (a) the descending genicular artery, a branch of the femoral artery (on the superomedial aspect), (b) the descending branch of the lateral femoral circumflex artery (on the superolateral aspect) and (c) anterior tibial recurrent artery, a branch of the anterior tibial artery (on the inferolateral aspect).

- The two superior genicular branches of the popliteal artery anastomose with each other in front of the femur
- The two inferior genicular arteries anastomose in front of the tibia

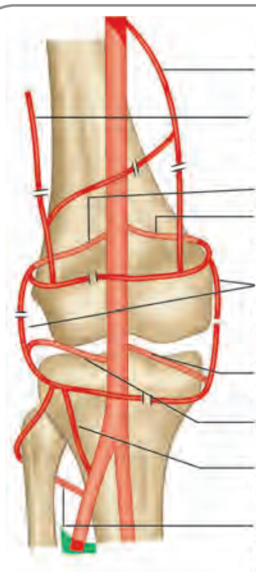


Fig. 25.7: Anastomoses around the knee joint

- The two medial arteries and the two lateral arteries are joined by vertical anastomoses
- Thus, a quadrilateral network is formed and this network liesmore on the anterior aspect of the knee joint
- This quadrilateral network is joined by the descending genicular branch of the femoral artery superomedially and the descending branch of the lateral circumflex femoral artery superolaterally
- Inferiorly, the recurrent branch of the anterior tibial artery and the circumflex fibular branch of the posterior tibial artery join the network.

This ***peri-articular genicular anastomosis***, as it is called, provides collateral circulation that will maintain the blood supply to the leg, even during complete knee flexion, at which time the popliteal artery is usually kinked and blood flow through it is halted.

ANASTOMOSIS ON THE BACK OF THIGH

The arteries in the back of the thigh join each other to form one or more vertical chains that can help maintain circulation in case of blockage or insufficiency of the main arterial trunk. The arteries taking part in these anastomoses are (from above downwards):

- The superior and inferior gluteal arteries
- The medial and lateral circumflex femoral arteries
- Perforating branches of the profunda femoris artery
- Muscular branches of the popliteal artery

Through these anastomoses, links are established between the internal iliac, femoral and popliteal arteries.

TIBIAL NERVE

This nerve is otherwise called the medial popliteal nerve and the posterior tibial nerve. It arises from the anterior divisions of L4,5,S1,2 and 3 and runs as a part of the sciatic trunk in the gluteal region and proximal thigh. At the superior angle of popliteal fossa, where the sciatic trunk divides into its constituent parts, the tibial nerve separates off and runs downwards to the leg. It continues further downwards and at the level of the ankle, takes a medial turn to go under cover of the flexor retinaculum, where it divides into its two terminal branches, namely, the medial and the lateral plantar nerves.

Course and Relations in the Popliteal fossa

In the popliteal fossa, where it is separated from the common peroneal nerve, it first lies under cover of the semimembranosus muscle. Then it becomes almost superficial, immediately deep to the fascia. It passes further downwards over the popliteal vessels, crossing them from lateral to medial side. Then it comes to lie on the popliteus muscle, under cover of gastrocnemius and plantaris and subsequently enters the back of leg.

Branches in the Popliteal fossa

These can be grouped into three sets.

Set 1: Articular branches to the knee: Two slender branches, one of which pierces the oblique popliteal ligament and the other accompanies the inferomedial genicular artery; both supply the structures of the knee joint.

Set 2: Muscular branches: Five branches; the branches to the two heads of gastrocnemius and the plantaris enter the concerned muscles at those aspects where they form the inferior borders of the popliteal fossa; the nerve to soleus enters the muscle on its superficial surface; the remaining nerve of this set, namely, the nerve to popliteus deserves special description. The nerve runs down on the posterior surface of the popliteus muscle, turns round its distal border and then supplies the muscle on its anterior surface. This nerve, as it turns round the distal border of the muscle, gives out muscular branches to the tibialis posterior, a branch to the interosseous membrane, an articular branch to the tibiofibular syndesmosis and a medullary branch to the tibia.

Set 3: Cutaneous branch: This is the sural nerve; from the popliteal fossa, the nerve runs between the two heads of gastrocnemius and then lies on the tendocalcaneus. It pierces the deep fascia in the middle third of the leg and becomes cutaneous. It is immediately joined by the peroneal communicating branch of the common peroneal nerve. It then runs downwards and reaches the foot by winding around the back of the lateral malleolus, along with the small saphenous vein The sural nerve gives cutaneous branches to the lateral aspect and back of the lower third of the leg, the ankle, the heel (the lateral calcaneal branches) and the lateral border of the foot and the little toe, articular branches to ankle and tarsal joints On the dorsum of the foot, the sural nerve communicates with the branches of the superficial peroneal nerve. Through this communication, it may reinforce or replace those branches of the superficial peroneal nerve to the adjacent sides of the 4th and 5th or the 3rd and 4th toes.

COMMON PERONEAL NERVE

This nerve is otherwise called the lateral popliteal nerve. It arises from the posterior divisions of L4, 5, S1 and 2. It forms part of the sciatic nerve in the gluteal region and the posterior thigh. From the bifurcation of the sciatic nerve at the superior angle of the popliteal fossa, the common peroneal nerve reaches its termination about an inch distal to the head of fibula.

Course and Relations in the Popliteal fossa

In the popliteal fossa, where it separates off from the tibial nerve, it is first under cover of the biceps femoris muscle. Following the tendon of this muscle, the nerve runs obliquely to he lateral part of the popliteal fossa and passes over the lateral head of gastrocnemius to reach the back of the head of fibula. As it reaches the fibula, the nerve lies quite superficial. Only at its termination, it is covered by the peroneus longus muscle and is actually between the neck of fibula around which it winds and the muscle.

Branches in the Popliteal fossa

These can be grouped into two sets.

Set 1: Cutaneous branches: The two cutaneous branches in this category are the lateral cutaneous nerve of the calf and the peroneal communicating nerve.

Lateral cutaneous nerve of the calf: It may be a single nerve or more in number. It arises in common with the peroneal communicating nerve in the popliteal fossa, pierces the deep fascia over the lateral head of gastrocnemius and supplies the skin and fascia of the lateral part of the back of leg in the upper two thirds.

Peroneal communicating branch: It arises in the popliteal fossa, passes over the lateral head of gastrocnemius but deep to the deep fascia and reaches the middle third of the leg. It joins the sural nerve in the middle third.

Set 2: Recurrent branch: It arises immediately proximal to the terminal division of the common peroneal and passes forward under cover of the peroneus longus. It then runs through the extensor digitorum longus and reaches the anterior compartment of leg below the lateral condyle of tibia. At this level, it divides into branches which supply the tibialis anterior muscle, the superior tibiofibular joint and the knee joint.

Terminal branches of the common peroneal nerve: These are the superficial and deep peroneal nerves. They arise immediately below the head of fibula and under cover of peroneus longus, run forward and subsequently diverge from one another.

POPLITEAL GROUP OF LYMPH NODES (FIG. 25.1)

The popliteal lymph nodes can be described in two groups; (1) the superficial group and (2) the deep group. The superficial popliteal lymph nodes are small and lie in the superficial fascia. One of them is a little large, lies at the point where the small saphenous vein pierces the deep fascia and receives lymph from the lymphatics that accompany the vein. The deep popliteal lymph nodes lie within the fat of the fossa and surround the popliteal artery and vein; they receive lymph from the lymphatics which accompany the deep veins and from the knee joint capsule The lymphatics from the popliteal lymph nodes follow the femoral vessels and drain into the inguinal lymph nodes.

Added Information

- On the surface, when the knee is flexed the popliteal fossa is usually seen as a diamond-shaped depression on the posterior aspect of knee. However, it is much larger than the superficial depression indicates because the fossa in reality extends deeper to the medial and lateral heads of gatrocnemius.
- When the knee is extended, the popliteal fat gives a smooth rounded appearance to the region of the fossa.
- The deep fascia or the popliteal fascia is a strong sheet, which is continuous superiorly with the fascia lata of thigh and inferiorly with the deep fascia of leg. It forms a protective covering for the neurovascular structures underneath and a retinacular band for the tendons of the hamstring muscles.
- On the deeper aspect, the superior boundaries of the fossa are the medial and lateral supracondylar lines of femur and the inferior boundary is the soleal line of tibia.
- When the leg is extended, the popliteal fascia is rendered taut; this compresses the fat within the popliteal fossa and pushes the semimembranosus muscle medially. The contents are thus protected.
- Among the contents of the popliteal fossa, the nerves are the most superficial, followed by the veins. The arteries are the deepest, lying directly on the floor structures.
- The fascia covering popliteus muscle is otherwise called the investing popliteus muscle.

Clinical Correlation

- The deep fascia of popliteal fossa does not permit expansion of the fossa Hence, abscesses or swellings in the fossa cause intense pain. Also because of the same reason, abscesses or tumours in the fossa tend to spread superiorly or inferiorly
- Because the popliteal artery is closely related to the femur and knee joint capsule, fractures of the distal femur and dislocations of knee can cause rupture of the artery.
- Injuries to the popliteal artery and vein can cause an arterio-venous shunt resulting in haemorrhage o loss of blood supply to the leg.
- A popliteal aneurysm (which is an abnormal dilatation of the artery) can cause pain and swelling in the popliteal fossa. Such an aneurysm can stretch the tibial nerve or intervene with the blood supply to the nerve. Pain from such a nerve compression is usually felt as a referred pain on the skin of the medial side of leg and foot.
- The collateral circulation established by the genicular anastomosis is of help when the femoral artery needs to be ligated. Blood passes through the anastomosis and reaches the popliteal artery.
- Varicosity of the terminal portion of the short saphenous vein may present as a swelling in the popliteal fossa.
- Inflammed and swollen bursae and synovial protrusions of knee joint may present as popliteal swellings.
- Injury to tibial nerve in the fossa (which is extremely rare due to the nerve's protected position) results in paralysis of posterior leg muscles and intrinsic muscles of the foot. The foot on the affected side is everted and dorsiflexed, making the individual walk on the heel.
- Injury to the common peroneal nerve in the fossa results in paralysis of the dorsiflexors and evertors of the foot. Foot drop deformity is seen and the individual walks on toes.

Multiple Choice Questions

1. Sural arteries:
   a. Are vessels supplying the extensor muscles of leg
   b. Are branches of profunda femoris artery
   c. Are muscular branches of popliteal artery
   d. Pierce the oblique popliteal ligament

2. The deep popliteal lymph nodes are:
   a. Nodes which surround the popliteal vessels
   b. Nodes which lie at the point where the small saphenous vein pierces deep fascia
   c. Nodes which receive afferents from inguinal lymph nodes
   d. Nodes which receive from medial side of leg, mons pubis and adductor compartment of thigh

3. Popliteal fascia is the:
   a. Superficial fascia of the region
   b. Deep fascia of the region
   c. Fascia over popliteus muscle
   d. Fascia extending deep to gastrocnemius muscle

4. Among the contents of popliteal fossa:
   a. Nerves are the most superficial and arteries the deepest
   b. Veins are the most superficial and arteries the deepest
   c. Arteries are the most superficial and nerves the deepest
   d. Nerves are the most superficial and veins the deepest

5 In its deeper aspect, the popliteal fossa extends inferiorly till:
   a. Plantaris muscle
   b. Soleal line of tibia
   c. Oblique popliteal ligament
   d. Intercondylar fossa

ANSWERS

1. c **2.** a **3.** b **4.** a **5.** b

Clinical Problem-solving

Case Study 1: A 45-year-old man complained of pain in the medial aspect of his leg. His physician after some investigations informed that some surgical procedure was to be done to his popliteal artery.

- What do you think was the condition? Substantiate your answer.
- Why did the patient have pain in the medial aspect of his leg?
- If femoral artery is ligated, how does blood reach the popliteal artery?

Case study 2: A 60-year-old man presented with a small swelling in the region of popliteal fossa. It was not painful. The man also had prominently beaded veins all over his leg.

- What do you think did the man have?
- In what way were the prominent veins of his leg and the popliteal swelling related?
- What is the reason that such a condition develops?

(For solutions see Appendix).

Chapter 26

Front of Leg and Dorsum of Foot

Frequently Asked Questions

- Discuss the muscles of the anterior compartment of leg.
- Describe the course, relations and branches of anterior tibial artery.
- Describe the course, relations and branches of dorsalis pedis artery.
- Discuss the Anterior Tibial nerve.

The ***leg*** is that part of the lower limb which lies between the knee and the ankle. It is otherwise, called the ***regio cruris*** (Latin.crus=leg). The ***foot,*** otherwise called the ***regio pes*** (Latin.pes=foot), is the distal part of the lower limb consisting of the tarsal, metatarsal and phalangeal regions.

COMPARTMENTS AND REGIONS OF THE LEG

The leg is divided into ***anterior***, ***lateral*** and ***posterior*** compartments by the two bones, namely—the tibia and fibula, the interosseous membrane between the bones and the two **intermuscular septa**. These septa are the extensions of deep fascia. The ***anterior intermuscular septum*** passes from the deep fascia to the anterior border of the fibula. It separates the anterior and lateral compartments. The ***posterior intermuscular septum*** passes from the deep fascia to the posterior border of the fibula. It separates the lateral and posterior compartments.

The anterior and posterior compartments are separated from each other by the ***interosseous membrane*** that stretches between the interosseous borders of the tibia and fibula The posterior compartment of the leg is divided into superficial, middle and deep parts by ***superficial*** and ***deep transverse septa***. Each of these compartments has its own blood and nerve supply.

Though three compartments are described, a cross-section of the leg reveals four regions. These are as follows—**(1)** ***anterior crural***, **(2)** ***lateral crural,*** **(3)** ***posterior crural*** and ***medial crural*** regions (Fig. 26.1). The anterior crural, lateral crural and posterior crural regions are the same as the anterior, lateral and posterior compartments respectively.

The ***medial crural region*** does not have a muscular or fascial compartment, therefore it is a region that overlies the subcutaneous medial surface of tibia. It is flat and smooth and passes down to merge with the subcutaneous medial surface of the medial malleolus of tibia. Traced upwards, it merges with the medial condyle of tibia. Though appearing insignificant, the medial crural region contains some

Dissection

With the cadaver in supine position and the leg properly placed (a block may be kept underneath and the foot placed in plantarflexion), study the bony landmarks of the region (Fig. 26.2).

Make a horizontal incision, at the level of the inferior part of ligamentum patella, through the anterior aspect of leg. Make another horizontal incision extending from one malleolus to the other Join these two by a vertical incision along the anterior border of tibia. In the lower part where the tibial border deviates, bring the incision down along the m dline to reach the inferior horizontal incision. In areas where the incisions do not run over periosteum or bone, take care not to plunge the scalpel deep so as to avoid injury to deeper structures. Reflect gently the lateral skin flap. The medial skin flap can also be reflected but with some resistance due to the underlying bone. However, try to preserve the superficial fascia in which the superficial veins can be seen.

Find and study the great saphenous vein, and cutaneous twigs of saphenous nerve, sural nerve and superficial peroneal nerve.

contd…

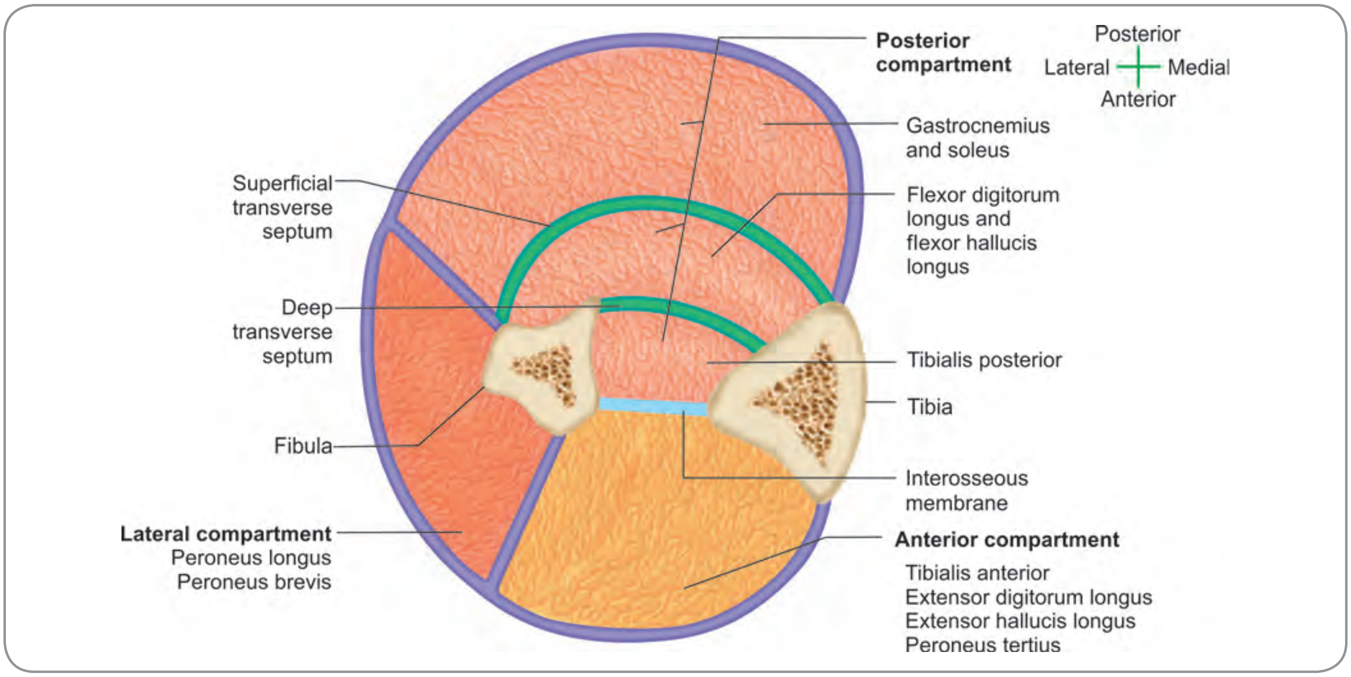


Fig. 26.1: Schematic diagram to show intermuscular septa and compartments of the leg

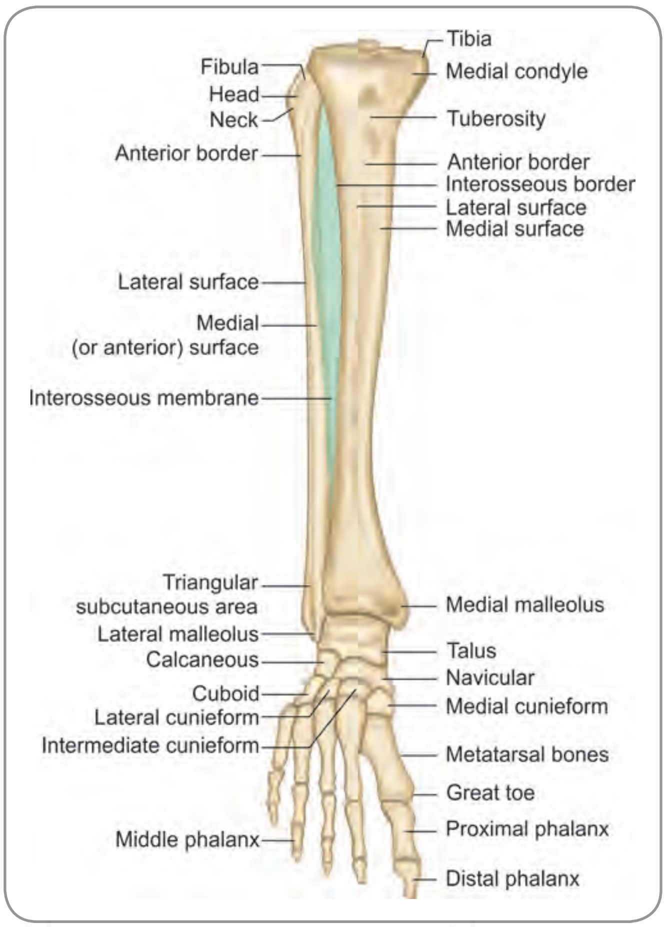


Fig. 26.2: Bony landmarks in front of leg and dorsum of foot

Dissection *contd...*

Extend the vertical incision on to the dorsum, keeping it in line with the axis line through the second toe. Make a transverse incision along the heads of metatarsals. The skin flaps of the dorsum can now be reflected and the structures of dorsum (especially the dorsal venous arch and the cutaneous twigs of deep peroneal nerve) can be studied along.

Identify and study the extensor retinacula. After these steps, remove the superficial fascia (still preserving the cutaneous veins and nerves). The deep fascia is now clearly seen. Make a small cut in the deep fascia immediately below the lateral condyle of tibia. Taking care not to injure the underlying structures, cut through the deep fascia vertically till the ankle with scissors.

important structures. The tendons of Sartorius, Gracilis and Semitendinosus get inserted to the medial surface of tibia above the level of the Tibial tuberosity. Each of these muscles is from a different compartment of the thigh and each is supplied by a different nerve (the nerve of the corresponding compartment). All three tendons cross the medial collateral ligament of knee to reach the medial condyle of tibia; but due to their different origins, a unique pattern of spiralling is established. The Sartorius, as it runs from in front, is superficial to the gracilis, which comes from the medial aspect. The gracilis, in turn, is superficial to semitendinosus which runs from the posterior aspect. All three of them flex the knee and rotate the leg medially.

The ***Great saphenous vein*** is another important structure seen in the medial crural region. It arises from

the medial end of the dorsal venous arch of the foot. It ascends up, crosses the medial surface of tibia in its lower third and then continues upwards a little posterior to the medial border of the tibia till the knee (from here, the vein runs up the thigh to reach the saphenous opening). The vein is accompanied by the Saphenous nerve but in the opposite direction. The nerve appears between Sartorius and gracilis, runs down along the vein and reaches the medial border of foot. It ends half way along the medial border of foot Throughout its course in the leg, the nerve gives out several cutaneous twigs which mostly pass deep to the saphenous vein to reach the skin.

The ***deep fascia of the leg*** is a firm sleeve that surrounds the internal structures of the leg like a 'stocking'. It is continuous above with fascia lata; and is attached to patella, ligamentum patellae, tibial tuberosity, tibial condyles and head of fibula. It binds the muscles and prevents them from swelling. On the posterior aspect, the deep fascia sends out a dense sheet to cover the popliteus muscle. This covering is called the ***fascia covering popliteus*** or the ***investing popliteus fascia***. From its undersurface, the deep fascia also gives out the anterior and posterior intermuscular septa and the superficial and deep transverse septa. These septa subdivide the leg into various musculo-fascial compartments. Around the ankle, the deep fascia forms a number of thickened bands which hold underlying tendons in place and also act as pulleys allowing the tendons to change direction. These bands are called ***retinacula.*** On the front of the ankle, are the ***superior*** and ***inferior extensor retinacula,*** on the lateral side are the (much less prominent) ***superior*** and ***inferior peroneal retinacula*** and on the medial side is present the ***flexor retinaculum***.

Dissection

Preserve the extensor retinacula. See the superior attachments of the anterior compartment muscles. Study the tendons of muscles as they pass under cover of the retinacula. Follow them upwards and downwards and define their attachments. Gently separate the muscles after cleaning them up; find the neurovascular bundle on the interosseous membrane. Trace them proximally as much as possible.

Trace the tendons of anterior compartment muscles into the dorsum; similarly trace the anterior tibial artery and deep peroneal nerve. See that the artery now is the dorsalis pedis.

Identify the extensor digitorum brevis muscle, the arcuate artery, the lateral tarsal artery, deep plantar artery and twigs of deep peroneal nerve.

Clean up the extensor expansion on the second toe.

ANTERIOR COMPARTMENT OF LEG AND DORSUM OF FOOT

The anterior compartment of the leg and the dorsum of foot are considered together because they make a single functional entity.

The ***anterior compartment***, otherwise called the ***dorsiflexor***, ***extensor*** or ***anterior tibio-fibular*** compartment of the leg, is anterior to the interosseous membrane and between the lateral surface of the tibia and medial surface of the fibula. It is covered anteriorly and anterolaterally by deep fascia and skin. The deep fascia is dense in the superior aspect. Inferiorly, it thickens to form the superior and the inferior extensor retinacula (singular. retinaculum). These two retinacula, lying above and below the ankle, hold the tendons of the muscles of the anterior compartment in place and prevent them from slipping forwards and bow stringing during dorsiflexion of ankle.

Extensor Retinacula (Fig. 26.3)

- The ***superior extensor retinaculum*** (otherwise called the ***transverse crural ligament*** or the ***transverse retinaculum***) is a strong transverse band about 3–4 cm broad. Laterally it is attached to the anterior aspect of fibula; medially it is attached to the anterior border of tibia, just above the medial malleolus and blends with the periosteum.
- The ***inferior extensor retinaculum*** (otherwise called the ***crucial crural ligament*** or the ***cruciate retinaculum***) is a Y shaped band which is present just in front of the ankle. Laterally, the stem of Y is attached to the upper surface of the calcaneus. Medially, the upper limb of Y blends with the periosteum of the medial malleolus; and the lower limb of Y, passing over the medial border of the foot, blends with the plantar fascia.

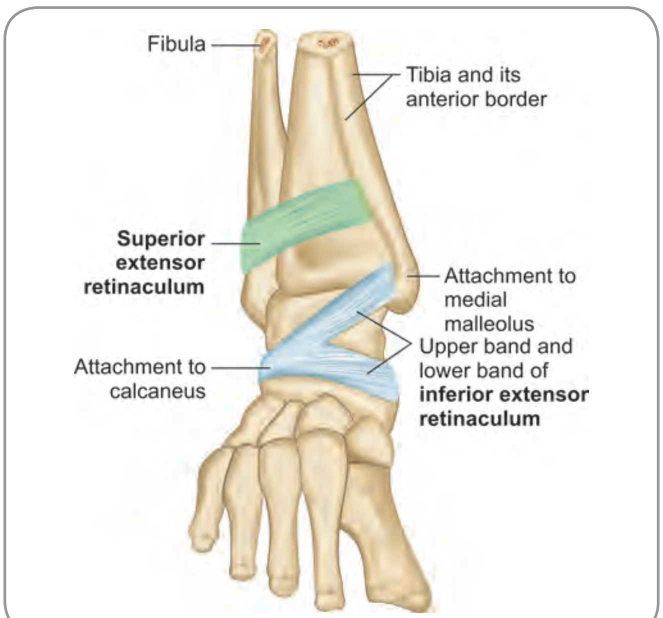


Fig. 26.3: Attachments of superior and inferior extensor retinacula

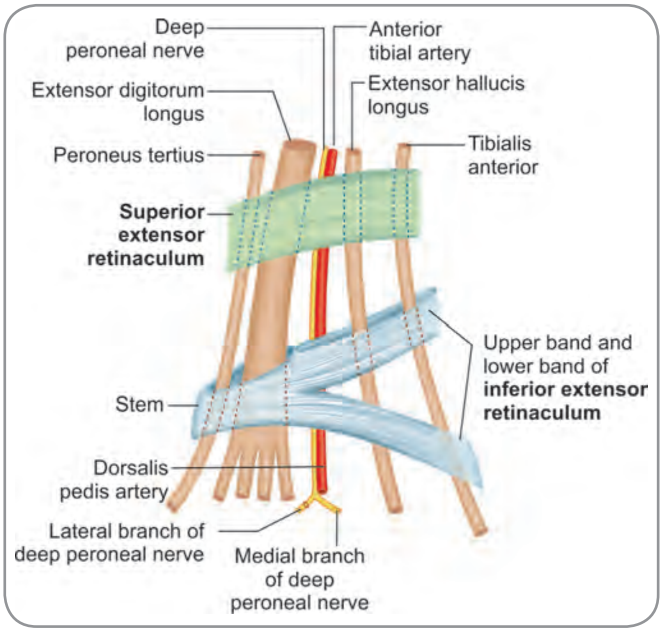


Fig. 26.4: Structures passing under cover of extensor retinacula

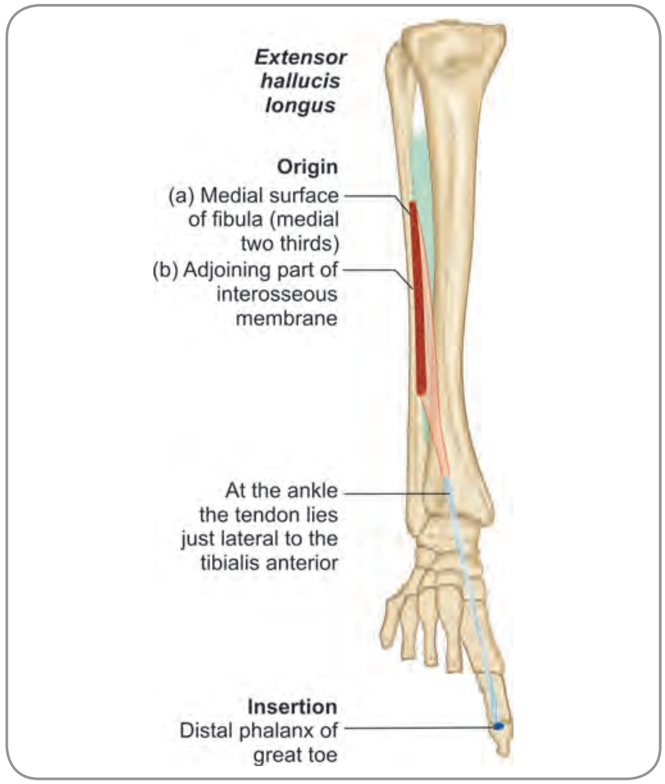


Fig. 26.5: Attachments of the extensor hallucis longus

Tendons Passing Under Cover of Extensor Retinacula and their Relationship

The tendons passing under cover of the extensor retinacula (Fig. 26 4) are (from medial to lateral side):

- Tibialis anterior
- Extensor hallucis longus
- Extensor digitorum longus and
- Peroneus tertius

  The superior extensor retinaculum is superficial to all the tendons.

  The relationship of the inferior extensor retinaculum to the tendons is as follows:

  - The stem of the Y, on its undersurface forms a loop through which the tendons of the extensor digitorum and peroneus tertius pass
  - The superior limb has two layers - one passing superficial to the extensor hallucis and the tibialis anterior, and the other deep to them
  - The inferior limb is superficial to these tendons; it may sometimes have an additional layer deep to the tendons.

MUSCLES OF ANTERIOR COMPARTMENT OF LEG AND DORSUM OF FOOT

The muscles of the anterior compartment are as follows (Table 26.1):

- Tibialis anterior
- Extensor hallucis longus; (Greek.hallux=great toe) (Fig. 26.5)
- Extensor digitorum longus and
- Peroneus tertius or (fibularis tertius). The term ***Tertius*** indicates ***third***; the muscle is so called because there are two other Peronei muscles (peroneus longus and peroneus brevis).

The muscle found in the dorsum of foot is the Extensor digitorum brevis.

The four muscles of the anterior compartment pass anterior to and are also inserted anterior to the axis of ankle joint (this axis is transversely oriented). Therefore, on contraction, they elevate the forefoot (front portion of the foot) and depress the heel. Thus, they are dorsiflexors of the ankle. The two longus muscles pass to be attached to the dorsal aspect of the toes, thus causing extension of the toes on contraction Though the movement of dorsiflexion is limited (only about 20 degrees from the normal position), it is an important movement in normal walking, in walking on rough surfaces, in prolonged standing and in descending slopes or stairs. During prolonged standing, when the body starts to lean backwards, the dorsiflexors pull the leg and keep the line of gravity forwards.

Synovial Sheaths of the Tendons

The tendons of the various muscles are invested with synovial sheaths called the ***tendon sheaths***. These sheaths provides lubrication and help in the movements of tendons over bones and firm surfaces. The tendons of the muscles of the anterior compartment have three separate sheaths:

Table 26.1: Muscles of anterior compartment of leg

Muscle	Origin	Insertion	Action	Nerve supply
Tibialis anterior	• Lateral surface of shaft of tibia (upper 1/2 to 2/3) • Interosseous membrane (adjoining)	• Medial cuneiform bone (medial and plantar aspect) • First metatarsal bone (medial side of base)	• Dorsiflexion of foot • Inversion of foot • Helps to maintain arches of foot	Deep peroneal nerve (L4, 5)
Extensor hallucis longus	• Medial surface of fibula (middle 2/4) • Interosseous membrane (adjoining) (Fig. 26.5)	Base of distal phalanx of great toe (dorsal aspect)	• Extends phalanges of great toe • Helps dorsiflexion of foot	Deep peroneal nerve (L5, S1)
Extensor digitorum longus	• Fibula (upper 3/4 of medial surface) • Interosseous membrane (for upper part of muscle only) (Fig. 26.6) • Uppermost part from lateral condyle of tibia	• Tendon divides into four slips one each for 2nd, 3rd, 4th and 5th toes (Figs. 26.7 and 26.8) • Over the proximal phalanx, the tendon (for that digit) divides into three slips one intermediate and two collateral • The intermediate slip is inserted into the base of the middle phalanx • The collateral slips reunite and are inserted into the base of the distal phalanx	• Extension of toes • Dorsiflexion of foot	Deep peroneal nerve (L5, S1)
Extensor digitorum brevis	Anterior part of calcaneus (on superior and lateral aspect) (Fig. 26.8)	• Muscle ends in four tendons (for first, second, third and fourth digits) • Tendons for 2nd to 4th digits joins the corresponding tendon of extensor digitorum longus • The tendon for the first digit is inserted into the dorsal surface of the base of the proximal phalanx of the great toe (Fig. 26.8)	• Helps extensor digitorum longus in extension of 2nd, 3rd, and 4th toes • Extension of proximal phalanx of great toe	Deep peroneal nerve (S1, 2)
Peroneus tertius	• Medial surface of shaft of fibula (below origin of extensor digitorum longus) • Interosseous membrane (adjoining)	Fifth metatarsal bone (dorsal surface of base)	• Dorsiflexion of foot • Eversion of foot	Deep peroneal nerve (L5, S1)

1. One for the tendon of ***tibialis anterior***,
2. One for the tendon of ***extensor hallucis longus*** and
3. One for the tendons of ***extensor digitorum longus*** and ***peroneus tertius***.

The tendon sheath of Tibialis anterior extends from the upper border of superior extensor retinaculum to almost near its insertion. The sheath of Extensor hallucis longus extends from midway between the two extensor retinacula to the proximal phalanx of big toe. The common sheath for Extensor digitorum longus and Peroneus tertius extends from lower border of inferior extensor retinaculum to the middle of the dorsum.

Additional Notes on the Dorsiflexors and Extensors

- The Tibialis anterior is the most medial and the most superficial of the dorsiflexors.
- As its insertion lies farther away from the ankle joint, the Tibialis anterior acquires great mechanical advantage and becomes the strongest dorsiflexor.
- The Peroneus tertius can be considered as a separate part of Extensor digitorum longus.
- The Peroneus tertius is an exclusive human muscle.
- The Extensor hallucis longus crosses the anterior tibial artery and is the only muscle to do so.
- That part of Extensor digitorum brevis serving the big toe is called the ***Extensor hallucis brevis***.
- The Extensor hallucis brevis crosses the dorsalis pedis artery and is the only muscle to do so.
- In the living person the tendon of the Tibialis anterior can be felt just lateral to the anterior border of the tibia, at the level of the ankle.
- Across the ankle, the tendon of Extensor Hallucis longus can be felt just lateral to the tendon of Tibialis anterior.

ARTERIES OF THE ANTERIOR COMPARTMENT AND DORSUM OF FOOT

The artery of the anterior compartment is the ***anterior tibial artery*** and that of the dorsum is the ***dorsalis***

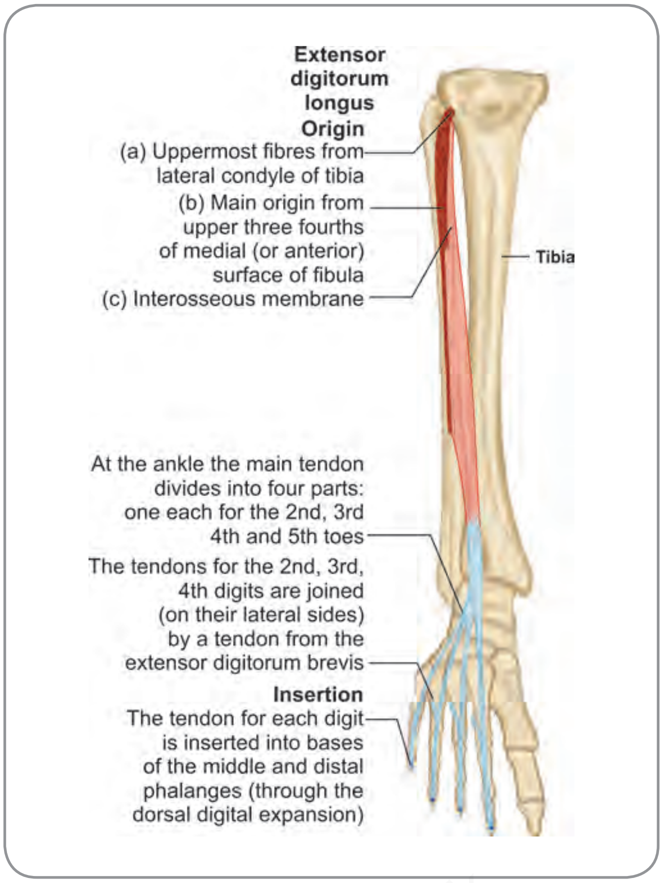


Fig. 26.6: Attachments of the extensor digitorum longus

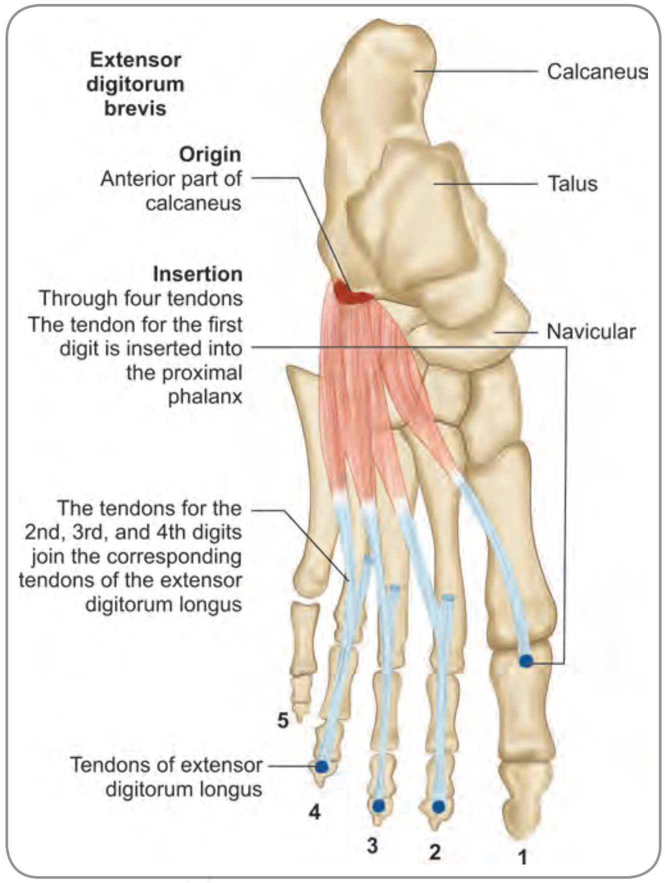


Fig. 26.8: Attachments of extensor digitorum brevis

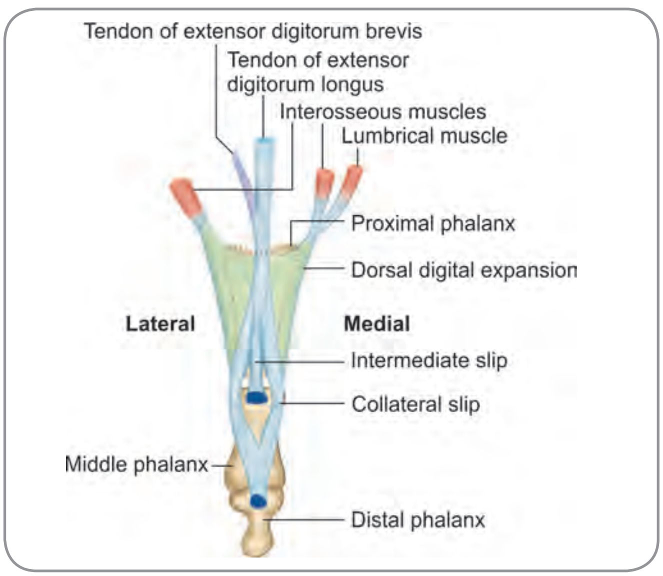


Fig. 26.7: Dorsal aspect of a digit to show the dorsal digital expansion and details of insertion of the extensor digitorum longus

pedis artery. However, dorsalis pedis artery is only a continuation of the anterior tibial artery and the two together are sometimes referred to as the ***great arterial trunk of the anterior crural region***.

Clinical Correlation

- All muscles of the anterior compartment are supplied by the deep peroneal nerve and have a common action, namely, dorsiflexion of the ankle. Paralysis of this muscle group leads to ***foot drop***, a condition where the foot is not able to dorsiflex and maintain its normal anatomical position. It is plantarflexed and thus is ***dropped***. While walking, the affected leg has to be lifted very high so as to prevent the toes from dragging on the ground or the leg tripping on the toes.
- Excessive (or unaccustomed) use of muscles of the anterior compartment can lead to oedema in the compartment and pressure on the deep peroneal nerve. This results is pain in the front of leg. Muscular swelling impedes venous return leading to further engorgement of the muscles and more swelling The condition is called the ***anterior compartment syndrome***. Since the deep fascia is unyielding, the contents of the compartment are compressed. Compression of the anterior tibial artery causes reduced blood supply to muscles, often leading to gangrene of leg or foot. Compression of the deep peroneal nerve causes weakness of muscles supplied and extensive pain in the region. Such compression is usually relieved by incising the fascia along the whole length of the compartment.
- Unaccustomed exercise of tibialis anterior causes pain in the shin region. This is called ***shin splints***.
- Excessive strain on the Tibialis anterior muscle (especially in athletes) produces small tears near its attachments. There is pain and edema over the lower two-thirds of the tibia.

Anterior Tibial Artery

Course and Relations (Fig. 26.9)

The ***anterior tibial artery*** begins as a terminal branch of the popliteal artery near the lower border of the popliteus muscle. Its commencement, therefore, is situated in the upper part of the back of the leg. Almost immediately, the artery turns forwards through a gap in the upper part of the interosseous membrane to enter the anterior compartment of the leg (Fig 26.9). It then descends over the anterior surface of the interosseous membrane. It gradually passes medially so that it comes to lie in front of the tibia in the lower part of the leg. In front of the ankle joint, midway between the medial and lateral malleoli, the anterior tibial artery continues as the ***dorsalis pedis*** artery.

In the upper part of the leg, the artery lies deep in the interval between the tibialis anterior, medially and the extensor digitorum longus. laterally, in the middle of the leg, it is related laterally to the extensor hallucis longus. The tendon of this muscle crosses the artery from lateral to medial side above the ankle. For a short distance above the ankle, the artery is covered only by skin, superficial fascia and deep fascia including the retinacula. Here it lies between the tendons of the extensor hallucis longus, medially and the extensor digitorum longus, laterally.

Throughout its course in the anterior compartment, the anterior tibial artery lies successively over the interosseous membrane, the lower part of the lateral surface of tibia and the anterior aspect of the ankle joint. The artery is accompanied by the deep peroneal (anterior tibial) nerve, which lies lateral to the artery.

Branches

The ***branches of the anterior tibial artery*** are as follows (Fig. 26.10):

- The ***anterior tibial recurrent artery:*** It arises anterior to the interosseous membrane, runs upwards through the substance of tibialis anterior and ascends to take part in the anastomosis around the knee. It is usually accompanied by the recurrent articular branch of the common peroneal nerve.
- The ***posterior tibial recurrent artery:*** It arises from the uppermost part of the anterior tibial artery in the back of the leg and supplies the superior tibiofibular joint.
- ***Numerous muscular branches:*** They supply the muscles of the anterior compartment of the leg.
- ***Cutaneous branches:*** They are many and supply the skin of the front of leg.
- The ***anterior medial malleolar artery:*** It arises near the ankle and runs to the medial malleolus.
- The ***anterior lateral malleolar artery:*** It arises near the ankle (usually opposite the medial malleolar artery) and runs to the lateral malleolus.

The malleolar arteries ramify over the corresponding malleolus and anastomose with other arteries in the region.

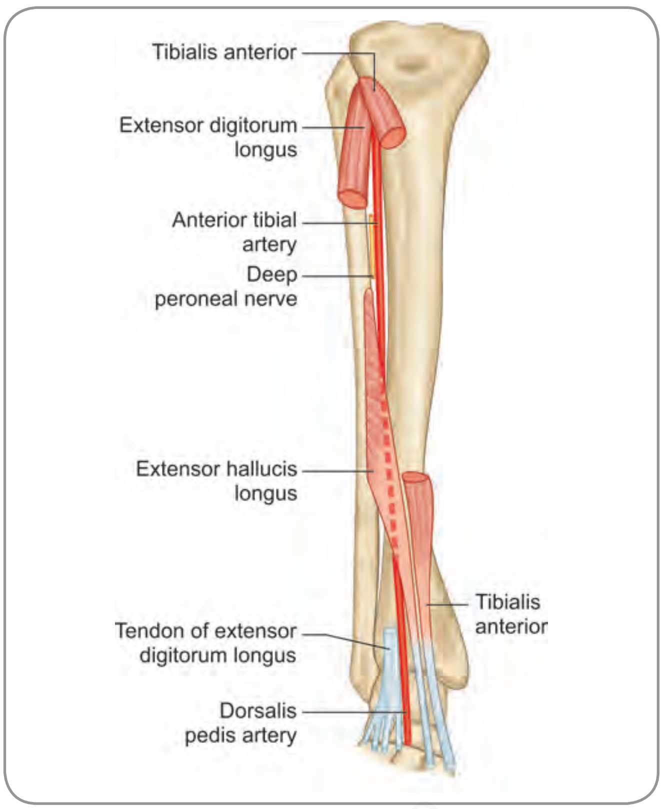


Fig. 26.9: Course and relations of the anterior tibial artery

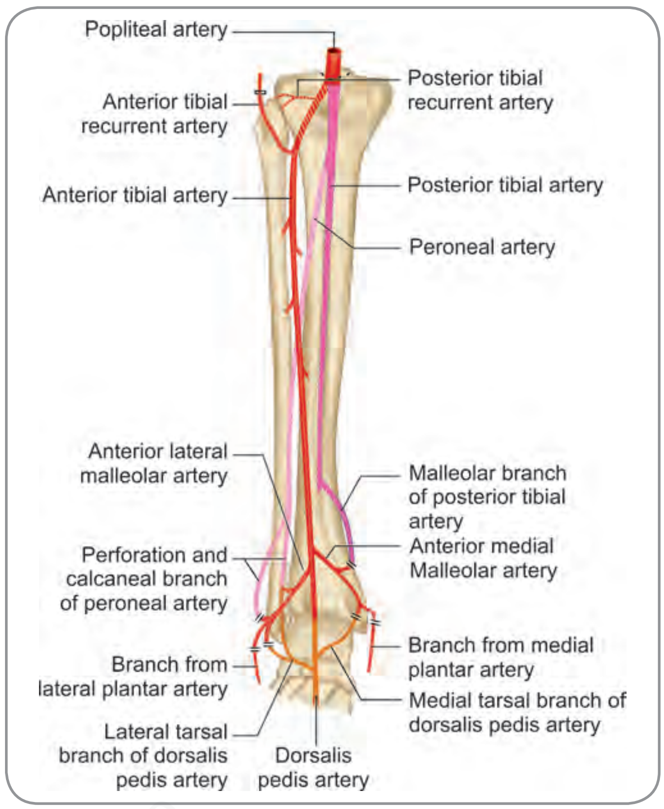


Fig. 26.10: Branches of the anterior tibial artery

Surface Anatomy

A broad line joining a point 2.5 cm below the medial side of the head of fibula and a point midway between the medial and the lateral malleolus. This line will run inferomedially and indicates the anterior tibial artery.

Dorsalis Pedis Artery

Course and Relations (Fig. 26.11)

Also called the ***dorsal artery of the foot,*** it is the continuation of the anterior tibial artery. Beginning in front of the ankle it runs forwards, downwards and medially on the dorsum of the foot to reach the space between the first and second metatarsal bones. Here it turns downwards through the space (between the two heads of the first dorsal interosseous muscle) to enter the sole of the foot. In the sole, it unites with the medial end of the plantar arch.

The artery is relatively superficial being covered only by skin and fascia. Its proximal part passes under cover of the inferior extensor retinaculum. Lateral to the artery is the tendon of the extensor digitorum longus, and the medial terminal branch of the deep peroneal nerve. The tendon of the extensor hallucis brevis crosses it from lateral to medial, to become its medial relation. From its commencement at the ankle till it dips down to enter the sole, the artery successively lies on the capsule of ankle and on the bony surfaces of talus, navicular and intermediate cuneiforms.

Branches

The branches of the dorsalis pedis on the dorsum are as follows (Fig. 26.12):

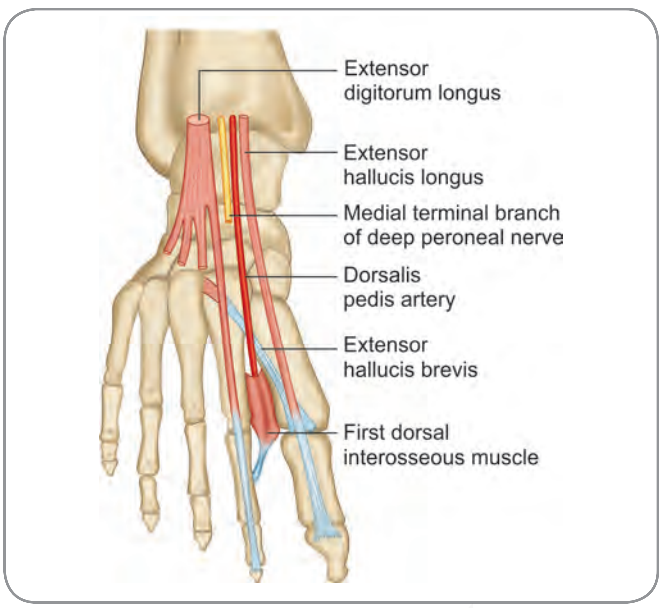


Fig. 26.11: Course and relations of dorsalis pedis artery

- The ***lateral tarsal artery:*** It arises immediately distal to the ankle, runs laterally, deep to extensor digitorum brevis, supplies the muscle and the skin over the lateral part of the dorsum.
- The ***medial tarsal arteries:*** These are small branches, arising on the dorsum and run up to the medial border of the foot, to supply the skin of that area.
- The ***arcuate artery:*** It arises just proximal to the first interdigital cleft, runs laterally deep to the long and short extensor tendons; it gives off the second, third and fourth dorsal metatarsal arteries, each of which runs forward in the corresponding interdigital space to reach the bases of the toes; and each divides into two dorsal digital arteries to the adjacent sides of the second and third, third and fourth, fourth and fifth toes respectively The lateral side of the little toe receives a branch from the fourth dorsal metatarsal artery

Each dorsal metatarsal artery also gives off two other branches called the ***anterior (distal) perforating branch*** and the ***posterior (proximal) perforating***

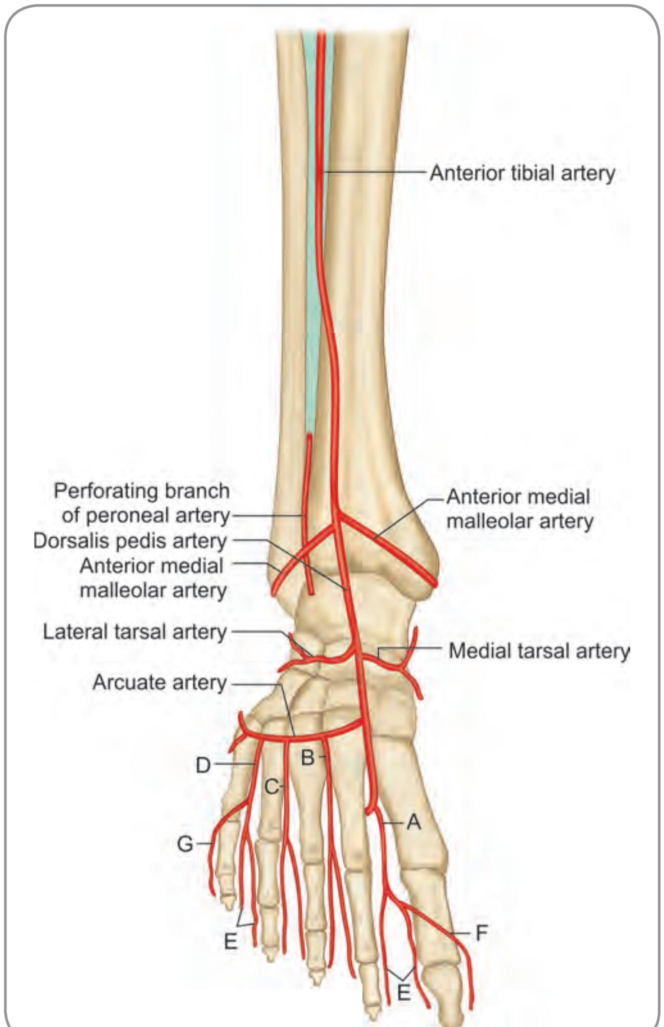


Fig. 26.12: Branches of dorsalis pedis artery. A–D=dorsal metatarsal arteries. E,F,G=dorsal digital arteries

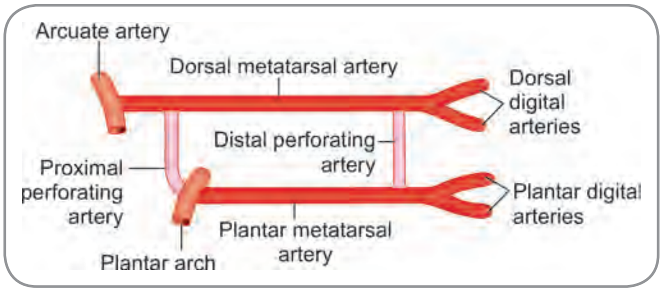


Fig. 26.13: The perforating arteries of the foot

branch. The anterior perforating branch passes between the heads of the dorsal interosseous muscle (of the corresponding interosseous space) and anastomoses with the corresponding plantar metatarsal artery (Fig. 26.13). The posterior perforating artery (otherwise called the deep plantar branch) also passes to the plantar aspect and anastomoses with the plantar arch.

- The ***first dorsal metatarsal artery:*** It arises as the dorsalis pedis dips into the sole and runs forward in the first interdigital cleft; it ends by dividing into dorsal digital branches which supply the adjacent sides of the big toe and the second toe, and the medial side of the big toe.
- The ***first plantar metatarsal artery:*** It arises as the dorsalis pedis unites with the lateral plantar artery; it then runs forward in the first interdigital cleft, gives a plantar digital artery to the medial side of the big toe and divides into two plantar digital arteries which supply the adjacent sides of the big and the second toe.

Surface Anatomy

A broad line joining the point opposite the ankle joint midway between the malleoli and a point on the proximal end of the first intermetatarsal space indicates the artery on the surface.

Added Information

- Though the anterior tibial is the main artery of the anterior conmpartment of leg, the perforating branch of the peroneal artery reinforces the supply. The sizes of the anterior tibial and the perforating branch are inversely proportional to each other.
- The dorsalis pedis is congenitally absent in about 10 to 16 percent of individuals.

Clinical Correlation

- The ***dorsalis pedis artery*** lies in front of the ankle where it can be palpated (the pedal pulse point) and pressed upon to stop the bleeding. Palpation of the pulse can be facilitated by slight dorsiflexion of the foot. If the dorsalis pedis pulse is absent, the reason may be—(1) congenital replacement of dorsalis pedis by a branch from the peroneal artery or (2) blockage due to arterial disease.
- Because the dorsalis pedis is superficially placed through most of its course and is closely related to the tarsal bones, it is often injured in wounds of the region.

NERVE OF THE ANTERIOR COMPARTMENT

Deep Peroneal Nerve

The ***deep peroneal nerve***, also called the **anterior tibial nerve**, or the **deep fibular nerve**, is the nerve of the anterior compartment. It is the larger of the two terminal branches of the common peroneal nerve. It begins on the lateral side of the neck of the fibula, deep to the peroneus longus. It passes downwards and medially, enters the anterior compartment of the leg and accompanied by the anterior tibial artery, descends in front of the interosseous membrane, first between the Tibialis anterior and Extensor digitorum longus and then between the Tibialis anterior and Extensor hallucis longus. It is crossed by the Extensor hallucis at the ankle. In the lower part of the leg, the nerve (along with the accompanying artery) takes a slight medial swerve. The tibia also widens here. Because of these two reasons, the deep peroneal nerve (and its accompanying artery) runs down on the anterior aspect of the shaft of the tibia. Still accompanied by the anterior tibial artery, it reaches the front of the ankle joint It ends here by dividing into lateral and medial terminal branches.

Muscular Branches

- In the leg the nerve gives branches to muscles of the anterior compartment, namely the tibialis anterior, the extensor hallucis longus, the extensor digitorum longus, and the peroneus tertius.
- The lateral terminal branch runs deep to the extensor digitorum brevis and enlarges into a pseudoganglion. From the pseudoganglion, a muscular branch to extensor digitorum brevis is given out.
- The medial terminal branch gives an interosseous branch to the first dorsal interosseous muscle.

Cutaneous Branches

The medial terminal branch runs forwards on the dorsum of the foot along with the dorsalis pedis artery, to the first interdigital cleft. It divides into two dorsal digital nerves which supply the adjacent sides of the great toe and the second toe.

Articular Branches

- An articular branch to the ankle joint is given out from the lower end of the deep peroneal nerve.
- The pseudoganglion of the lateral terminal branch gives three branches (called the interosseous branches) to the tarsal and metatarsal joints of the middle three toes. One of these branches also gives a muscular branch to the second dorsal interosseous muscle.
- The metatarsophalangeal joint of the great toe receives a branch from the medial terminal branch.

Surface Anatomy

A line joining a point on the lateral side of the neck of fibula and another point midway between the two malleoli will mark the nerve on the surface. This line, in the upper third of the leg should have a mild lateral concavity; in the rest of its course, it should run vertically down. While marking the nerve, it should be remembered that the nerve is lateral to the anterior tibial artery in the upper and lower parts, but anterior in the middle.

A line closely parallel but lateral to the dorsalis pedis artery will mark the medial terminal branch of the deep peroneal nerve.

Added Information

- The deep peroneal nerve is otherwise called the ***nervus hesitans***. This name is due to the unique relation it has with the anterior tibial artery. At the upper part of leg, the nerve is lateral to the artery. In the middle, it becomes anterior. However, once again in the lower part, the nerve resumes its lateral position. It appears as though the nerve is hesitant to cross the artery. Hence, the name.
- The deep peroneal nerve corresponds to the posterior interosseous nerve of the forearm.

Clinical Correlation

- The deep peroneal nerve may be compressed in anterior compartment syndrome or in individuals wearing tight foot wear. Paralysis of the anterior compartment muscles and loss of sensation over the first interdigital cleft results.
- Paralysis of the anterior compartment muscles (the dorsiflexors) causes ***foot drop***. Foot drop can also occur in injury to the common peroneal nerve or in diseases like leprosy and peripheral neuritis when the nerve is affected.
- Ingrowing Toe Nail: In this condition, seen in the big toe, one end of the distal edge of the nail grows into soft tissue causing pain and setting up inflammation. The condition can be prevented by trimming the nail straight (not curved) and making sure that it does not grow into soft tissue. In serious cases, part of the nail may need removal.
- Paronychia: This is the infection of soft tissue in relation to a nail bed.

Multiple Choice Questions

1. Cruciate retinaculum (of leg) is:
  a. The same as superior extensor retinaculum
  b. Y-shaped
  c. Located above the medial malleolus
  d. Also called the transverse crural ligament

2. Tibialis anterior is the strongest dorsiflexor of the ankle:
  a. Because it is the most superficial of the dorsiflexors
  b. Because it is the most medial of the dorsiflexors
  c. Because its insertion is farther away from ankle joint
  d. Because it has a strong nerve supply

3. Shin splints is caused by:
  a. Paralysis of deep peroneal nerve
  b. Pressure on deep peroneal nerve
  c. Unaccustomed exercise
  d. Dragging of foot

4. In the anterior compartment, the anterior tibial artery:
  a. Descends over the interosseous membrane
  b. Lies lateral to the anterior tibial nerve
  c. Divides into two terminal branches
  d. Gives off the lateral tarsal artery

5. Deep peroneal nerve is called nervus hesitans because:
  a. It is lateral to the deep peroneal nerve
  b. It appears to hesitate to cross the artery
  c. It corresponds to the posterior interosseous nerve of forearm
  d. It runs on the shaft of tibia before dividing into terminal branches

ANSWERS

1. b **2.** c **3.** c **4** a **5.** b

Clinical Problem-solving

Case Study 1: A 24-year-old man came to the clinic with complaints of numbness over the right first interdigital cleft for about 2 months. He also had difficulty in walking and had to drag his right foot; he felt his right foot was drooping down and because of this, he was tripping whenever he tried to walk fast. On examination, there was no swelling, no oedema or discolouration. The second time the man came in, the physician noticed a few pressure marks and the man said he had just removed his shoes.

- What is the most probable cause for numbness and difficulty in walking?
- When the man said he was dragging his foot, what condition would you have expected? What is the confirmation?
- How would you rule out anterior compartment syndrome or any other higher cause for the same symptoms?

Case Study 2: A 35-year-old man came with complaints of pain, swelling and redness over the nail of his right big toe. On examination, the nail appeared rolled up like a spiral and was found poking into the adjacent tissue.

- What condition was this man suffering from?
- Why was the nail rolled up and what was it trying to do?
- What kind of foot wear would you advocate to this man?

(For solutions see Appendix).

Chapter 27

Lateral Compartment of Leg

Frequently Asked Questions

- Discuss the peroneal (or fibularis) muscles.
- Write notes on (a) Peroneal retinacula, (b) Triple nerve relationship of peroneus longus, (c) Actions of peroneus longus, (d) Course and attachments of tendon of peroneus longus
- Discuss the superficial peroneal nerve.

The ***lateral compartment*** of leg, otherwise called the ***evertor, fibular or peroneal compartment,*** is the narrowest (and hence, the smallest) of the leg compartments. It is located in the area bounded by the anterior intermuscular septum, the lateral surface of fibula and the posterior intermuscular septum. Thus, the compartment is posterolateral to the anterior septum, lateral to fibula and anterior to the posterior septum. It is covered externally by the deep and superficial fasciae and skin.

The deep fascia thickens near the ankle to form the peroneal retinacula. Though the peroneal retinacula are not as thick or prominent as the extensor retinacula, they serve similar purposes of holding the tendons in place and preventing bowstringing.

PERONEAL RETINACULA

The peroneal retinacula (otherwise called the external annular retinacula) are present on the lateral aspect of the ankle (Fig. 27.1). They keep the peroneal tendons in place.

- The ***superior peroneal retinaculum*** is attached above to the lateral malleolus and below to the lateral surface of the calcaneus.
- The ***inferior peroneal retinaculum*** is attached below to the lateral surface of the calcaneus. Above, it becomes continuous with the inferior extensor retinaculum. On the deeper aspect, this retinaculum forms loops for the tendons of the muscles of the lateral compartment.

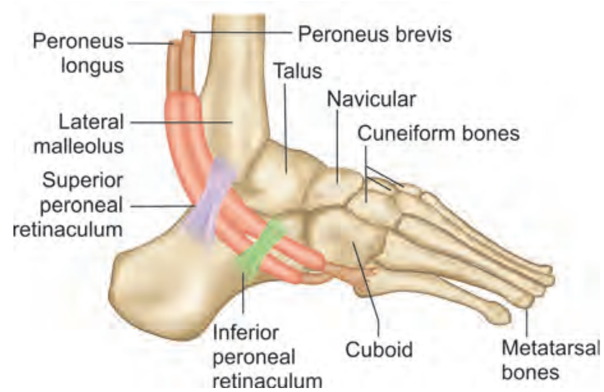


Fig. 27.1: Lateral side of ankle and foot to show the peroneal retinacula and synovial sheaths of peroneal tendons

Dissection

It is better to study the lateral compartment of leg along with the anterior compartment.

Since the anterior compartment is already exposed, the skin flap of the same can now be reflected little more laterally to expose the lateral compartment. Study the deep fascia and the peroneal retinacula. Identify the superficial peroneal nerve as it emerges on the superficial fascia and trace its branches into the dorsum

Make a vertical incision on the deep fascia, reflect and study the peroneal muscles. Separate the muscles from each other with your fingers. Identify the muscular nervous branches and trace them to their origin.

By careful blunt dissection, trace the superficial peroneal nerve proximally so as to reach the common peroneal nerve. If necessary, split the peroneus longus muscle transversely to expose the common peroneal nerve and its divisions. Try to follow the deep peroneal nerve till where it already has been exposed in the anterior compartment.

Define the muscles and trace their tendons. See that the peroneus longus tendon enters the sole; trace the peroneus brevis tendon to its insertion.

Table 27.1: Muscles of lateral compartment of leg (peroneal or fibular muscles)

Muscle	Origin	Insertion	Action	Nerve supply
Peroneus longus (fibularis longus) (Fig. 27.2)	• Head of fibula • Lateral surface of fibula (upper two-thirds)	The tendon passes: • Behind lateral malleolus • Across lateral surface of calcaneus • Round cuboid bone to enter the sole. It runs medially across the sole • The tendon is attached to: – First metatarsal bone (lateral side of base) – Medial cuneiform bone (lateral side)	• Eversion of foot • Steadies the leg on the foot (especially while standing on one foot) • Maintains arches of foot	Superficial peroneal nerve (L5 S1, S2)
Peroneus brevis (fibularis brevis) (Fig 27.3)	Shaft of fibula (lower two-thirds of lateral surface)	• Tendon passes behind lateral mal eolus, (lying anterior to that of peroneus longus) • Runs forward on lateral side of calcaneus • Tendon gets inserted into fifth metatarsal bone (lateral side of base)	• Eversion of foot • Steadies the leg on the foot	Superficial peroneal nerve (L5, S1, S2)

MUSCLES OF LATERAL COMPARTMENT OF LEG

These are as follows:

- Peroneus longus (or Fibularis longus) (Greek.perone = fibula) (Table 27.1);
- Peroneus brevis (or Fibularis brevis).

The two muscles have their fleshy bellies in the lateral compartment, but become tendinous as they pass under cover of the superior peroneal retinaculum. Both are evertors of the foot, acting on the subtalar joints and elevating the lateral margin of the foot. In reality and in normal circumstances, eversion is a limited movement. The two evertors, in addition to elevating the lateral margin of the foot, depress and fix the medial margin. During normal walking, running and walking on uneven grounds, the action of fixing the medial margin prevents excessive inversion of the foot (the position in which the ankle is more prone for injury). In prolonged standing, the evertors pull the leg laterally; this helps in maintaining the line of gravity.

Synovial Sheaths of the Tendons

As the tendons of peroneus longus and brevis pass on the lateral aspect of the ankle and foot, they are together enclosed in a common tendon sheath. It begins immediately behind the lateral malleolus close to the peroneal trochlea, the sheath splits into two. The part on the peroneus brevis extends till the insertion of the muscle. The part on the peroneus longus continues across (sometimes with one or two interruptions) the sole till the insertion.

Additional Notes on the Evertors

- The peroneus longus is the longer and the more superficial of the two muscles.
- There is a gap between the areas of origin of peroneus longus from the head of the fibula and from the shaft. The common peroneal nerve passes through this gap.
- The peroneus longus ends in a tendon that passes along a groove behind the lateral malleolus; here it is covered by the superior peroneal retinaculum. The tendon then runs along the lateral aspect of the calcaneus. It passes just below the peroneal trochlea (or the fibular trochlea), where the tendon is covered by the inferior

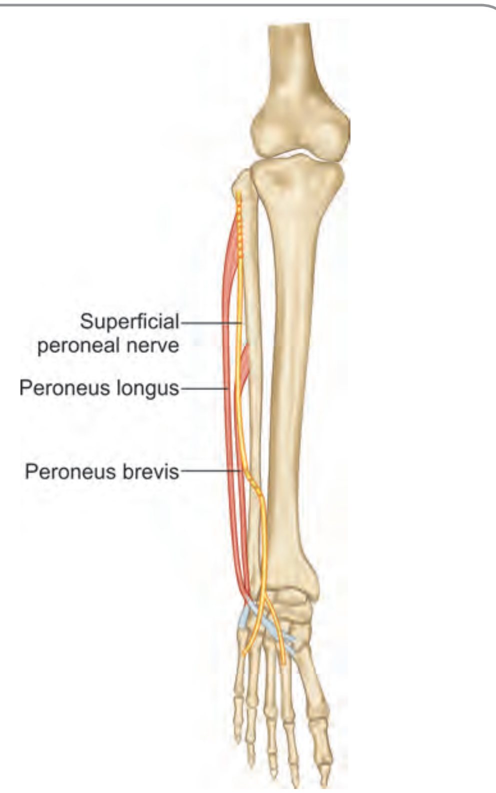


Fig. 27.2: Muscles of lateral compartment of leg

peroneal retinaculum. Thereafter, the tendon winds around the lateral side of the cuboid bone to reach its plantar aspect. This aspect of the cuboid bone bears a groove for the tendon (which is converted into a canal by the long plantar ligament).

- The tendon of peroneus longus is very long and changes direction in two places, one at the lateral malleolus and the other at the cuboid.
- The peroneus longus crosses the ankle behind the transverse axis; so it produces plantar flexion. It turns around the cuboid to reach the sole; so it produces eversion. It crosses the width of the sole obliquely; so it helps in maintenance of the longitudinal and transverse arches of the foot.
- The common peroneal nerve and its two terminal branches lie deep to peroneus longus, at the neck of fibula. This forms the 'triple nerve' relationship of the muscle.
- Due to the fact that the posterior border of the fibula turns medially in its lower part, the area of origin of the peroneus brevis (on the lateral surface) extends onto the posterior aspect of the bone.
- At the ankle, the peroneus brevis tendon passes behind the lateral malleolus; here it lies anterior to the tendon of the peroneus longus. It then runs forwards on the lateral surface of the calcaneus; here it lies above the longus tendon, the two being separated by the peroneal trochlea.
- Peroneus longus helps to maintain the arches of the foot (both longitudinal and transverse).
- Muscular slips from peroneus brevis may sometimes join the peroneus longus; these slips form the peroneus accessorius.
- If a musculotendinous slip of peroneus brevis joins the extensor digitorum longus tendon to the little toe, it is called the ***peroneus digiti minimi***.
- Eversion is a specific and characteristic movement of the human foot.

Clinical Correlation

Tenosynovitis of peronei is a condition where the tendon sheaths of the peroneal muscles are inflammed.

BLOOD VESSELS OF THE LATERAL COMPARTMENT

The lateral compartment does not have a separate artery as the other two compartments of the leg. An artery called the peroneal artery runs in the posterior compartment. Muscular branches from this artery supply the muscles of the lateral compartment and a nutrient branch supplies the fibula.

NERVES OF THE LATERAL COMPARTMENT

Superficial Peroneal (Fibular) Nerve

Course and Relations

The superficial peroneal nerve, also called the ***superficial fibular nerve*** or the ***musculocutaneous nerve***, is the smaller of the two terminal branches of the common peroneal nerve. It begins at the neck of the fibula deep to the peroneus longus. It runs downwards and obliquely forward on the shaft of fibula until it reaches the peroneus brevis muscle. At the junction of the middle and the lower thirds of the leg, the nerve becomes cutaneous. Just above the ankle, it divides into medial and lateral terminal branches that descend across the ankle to reach the dorsum of the foot.

Muscular Branches

Both the muscles of the lateral compartment are supplied by muscular branches which are given out in the upper part of the compartment when the nerve is descending between the two muscles (the intermuscular plane of the compartment).

Cutaneous Branches

Branches are given out from the nerve in the lower third of the leg, these branches supply the skin of the lateral side of the leg. Each terminal branch divides into two dorsal digital nerves.

- The medial branch gives one dorsal digital nerve to the medial side of the great toe; and another to the adjacent sides of the second and third toes.
- The lateral branch gives one dorsal digital nerve to the contiguous sides of the third and fourth toes and another to the adjacent sides of the fourth and fifth toes.
- The stems of both the medial and lateral branches supply twigs to the skin of the intermediary area of dorsum.
- The lateral terminal branch also supplies the skin on the lateral side of the ankle.

Communicating Branches

The medial terminal branch gives out communicating branches to the deep peroneal and the saphenous nerves. The lateral terminal branch gives out a communicating branch to the sural nerve.

Surface Anatomy

A line joining a point on the lateral aspect of the neck of fibula and a point on the anterior aspect of peroneus longus at the level of the junction of the middle and the lower thirds of the leg marks the nerve on the surface

Clinical Correlation

Injury to superficial peroneal nerve

The nerve can be stretched in athletes This is associated with sprains of the ankle. There is pain along the lateral side of the leg and dorsum of the foot. The evertors are weakened or paralysed. Sensory loss on the lateral part of leg, ankle, over the dorsum and over the dorsum of all digits except the first interdigital cleft is noticed. If the evertors are paralysed, the movement of eversion is lost.

Multiple Choice Questions

1. Musculo cutaneous nerve of leg:
   a. Becomes cutaneous in the upper third of leg
   b. Continues as a single trunk into the dorsum of foot
   c Gives out muscular branches when in the intermuscular plane of peroneal compartment
   d. Commences in the inferior part of popliteal fossa as a smaller division of common peroneal nerve

2. Peroneus digiti minimi is:
   a. A separate muscle of the dorsum of foot
   b. A slip of peroneus longus joining extensor digitorum brevis in the dorsum
   c. A slip of peroneus brevis joining extensor digitorum longus in the dorsum
   d. Part of peroneus accessorius

3. Peroneus longus produces plantarflexion because:
   a. It passes behind the transverse axis of ankle joint
   b. It changes direction in two places
   c. Turns around the cuboid to reach the sole
   d. Has a triple nerve relationship

4. The evertor muscles:
   a. Also cause elevation of the medial border of foot during running
   b. Pull the leg laterally during long hours of standing
   c. Depress the foot as a whole during walking on uneven ground
   d Have no role during normal walking

5. With regard to peroneal retinacula, which is correct:
   a. Superiorly both get attached to lateral malleolus
   b. They do not prevent bowstringing of peroneal tendons
   c. The superior retinaculum forms loops for the muscles in its deeper aspect
   d. They are also called external annular retinacula

ANSWERS

1. c **2.** c **3.** a **4.** b **5.** d

Clinical Problem-solving

Case Study 1: A medical school student was walking on a hilly terrain. He noticed that there was a tendency for his feet to go into partial eversion more often than into inversion and the medial margins of his feet were being strongly placed to the ground.

- Was the student correct in his observation? If so, what was abnormal with him?
- What is the reason for this tendency?
- Which muscles produce such a tendency and what is the functional significance?

Case Study 2: A sportsman sustained a left ankle sprain However, as he was medicated and the pain around his ankle subsided, he observed that he had diffuse pain over the lower lateral part of his left leg and the whole of dorsum. On closer look, he was convinced that there was no pain over a small patch in the first inter digital area.

- What do you think was the man suffering from?
- Correlate the symptoms with your idea of diagnosis.
- What else would you check in this patient?

(For solutions see Appendix)

Chapter 28

Back of Leg and Sole of Foot

Frequently Asked Questions

- Write notes on (a) Flexor retinaculum, (b) Soleus, (c) Popliteus, (d) Plantaris, (e) Fibrous flexor sheath.
- Discuss the popliteus muscle and its actions.
- Describe the course and distribution of the tibial nerve.
- Discuss the plantar aponeurosis in detail.
- Write notes on (a) Quadratus plantae, (b) Adductor hallucis, (c) Interossei, (d) Lumbricals, (e) Flexor digitorum brevis.

Back of leg is also called the ***calf***. If the leg of the lower limb corresponds to the forearm of the upper limb, then back of leg corresponds to the front of forearm. Since the structures in the back of leg continue into the sole, it is customary and also convenient to consider the back of leg and the sole of foot together. Both, it should be remembered, are flexor in function.

Dissection

If popliteal fossa and anterior compartment are already dissected, care must be exercised to preserve some skin attachment so that the dissected areas can be kept covered. If the posterior compartment is the first one to be studied, make the following skin incisions (cadaver in prone position—lower limb well stretched):

- a horizontal incision at the junction of middle and lower thirds of thigh;
- a curved horizontal incision on the distal part of heel;
- a vertical incision along the middle of the posterior aspect, connecting the two horizontal incisions.

Reflect the skin flaps medially and laterally. Several cutaneous vessels and nerves can be seen. Try to identify the sural nerve and the small saphenous vein inferior to the lateral malleolus. Trace thei branches and tributaries respectively. Look out for small medial calanean nerves on the medial aspect of heel. Try to find the communication between sural and peroneal communicating nerves. Trace the sural nerve upwards to the tibial nerve, and the peroneal communicating nerve to the common peroneal nerve. Clean up intervening fascia.

contd...

Dissection *contd...*

Identify and define the flexor retinaculum. Identify the structures passing under cover of it.

Hold the tendocalcaneus. Follow it upwards. Identify the two heads of gastrocnemius. Separate them to view contents of popliteal fossa. Try to identify the bursae near the medial head. After defining the heads and after making out the plantaris under cover of the lateral head, cut through both the heads. Reflect the superior and inferior cut portions. Identify the soleus muscle and define it. Note that the tibial vessels and the tibial nerve pass deep to a tendinous arch in soleus. Trace the tendon of plantaris and fibres of soleus to the tendocalcaneus. Clean above the soleus to see the popliteus muscle. Try to identify the nerve to popliteus which runs on the muscle's posterior surface to wind around the inferior border.

Transect the soleus below the tendinous arch and reflect it down. The superficial transverse septum is seen. Cut through the septum vertically. The long flexors and the neurovascular bundle are exposed. Study them. As you trace the tendons of long flexors to the flexor retinaculum, try to look for the peroneal artery deep to the flexor hallucis longus. Separate the long flexors to expose the deep transverse septum. Incise the septum vertically to expose the Tibialis posterior.

POSTERIOR COMPARTMENT OF LEG

The ***posterior compartment*** is the largest of the three compartments of the leg. Superiorly, it is continuous with the popliteal fossa and inferiorly with the sole of foot. It lies posterior to the bones of the leg, the interosseous membrane and the posterior intermuscular septum.

Fascial extensions subdivide the compartment (Fig. 28.1). There are two such extensions, namely the ***superficial transverse septum*** and the ***deep transverse septum***. The superficial transverse septum is well defined; it is attached superiorly to the soleal line of tibia, medially to the medial border of tibia, laterally to the posterior border of fibula and

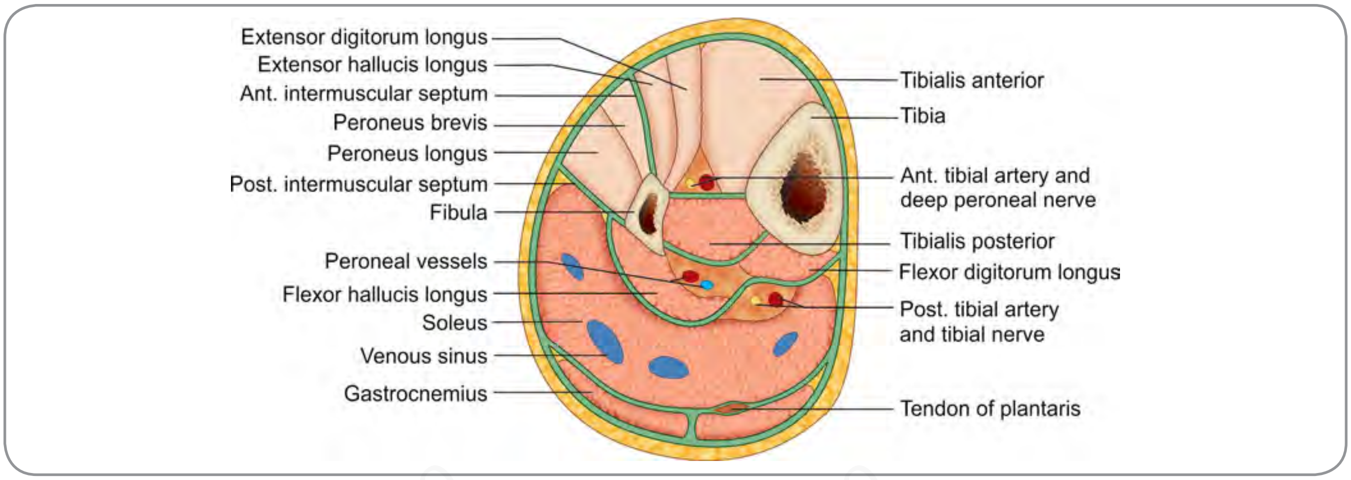


Fig. 28.1: Transverse section showing the septa and muscles of the posterior compartment

inferiorly is continuous with flexor retinaculum. Superficial to the superficial septum are the superficial muscles of the calf consisting of the Gastrocnemius, soleus and plantaris (superficial part of the posterior compartment). Deep to the superficial septum are the plantar flexors with the neurovascular bundle of the posterior compartment A deep transverse septum extends between tibia and fibula, further subdividing the deep region into a middle and a deep part. In the middle part are the Popliteus, Flexor digitorum longus, Flexor hallucis longus the posterior tibial artery, the peroneal artery and the tibial nerve. In the deep part is the Tibialis posterior.

FLEXOR RETINACULUM (FIG. 28.2)

It is also called the ***laciniate ligament***. It is a thickening of the deep fascia, present on the medial side of the ankle. It is attached above (actually, the medial end) to the medial malleolus, and below (actually, the lateral end) to the medial surface of the calcaneus. The fibres of the retinaculum are directed downwards, backwards and laterally. Superiorly (or proximally to be précise) the retinaculum is continuous with the deep fascia of the leg, especially with the superficial transverse septum that covers the long flexor muscles. Inferiorly (or distally) it is continuous with the deep fascia of the sole. From the deep surface of the retinaculum, fibrous septa run to the lower end of tibia and the ankle joint. These septa subdivide the space under cover of the retinaculum into four tunnels. The structures passing under cover of the retinaculum, run in these tunnels and are as follows (from above downwards, and also from medial to lateral side):

- Tendon of the tibialis posterior—first tunnel
- Tendon of the flexor digitorum longus—second tunnel
- Posterior tibial vessels and tibial nerve—third tunnel
- Tendon of the flexor hallucis longus—fourth tunnel

At the distal aspect, fibres of abductor hallucis take origin from the retinaculum. Medial calcaneal artery (a branch of posterior tibial artery) and the medial calcaneal nerve (a branch of tibial nerve) pierce the retinaculum.

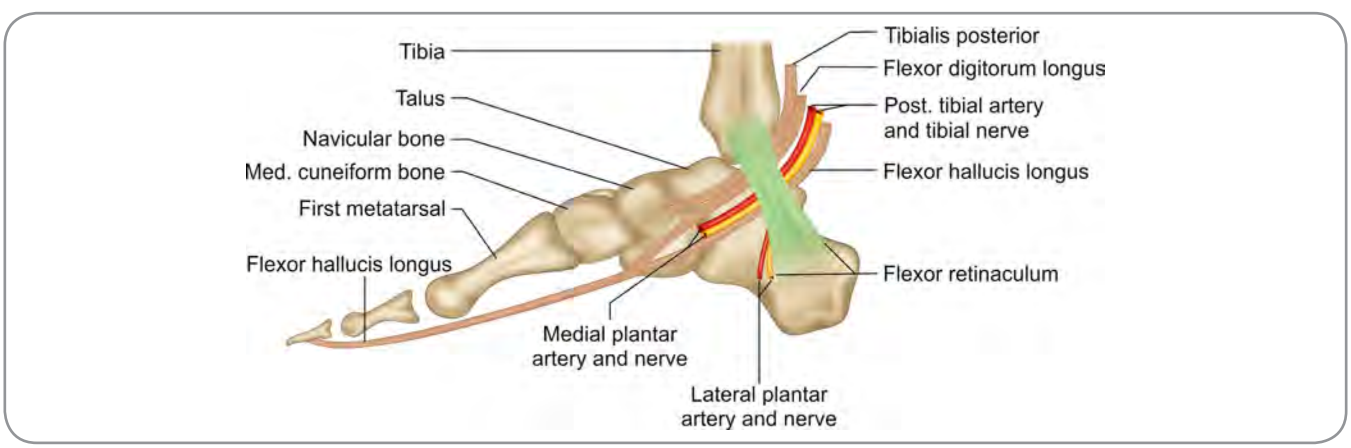


Fig. 28.2: Flexor Retinaculum and structures passing deep to it

Clinical Correlation

The flexor retinaculum forms an osseofibrous tunnel (the tarsal tunnel) on its deep surface; tendons and neurovascular structures pass through this tunnel from the posterior compartment of leg to the sole. A dense retinaculum, if it is tight, can compress the underlying structures. Swelling of the tendons due to tenosynovitis (inflammation of the tendons and their synovial sheaths) can also predispose to compression because of the limited space. Compression of the tibial nerve causes tingling and burning sensations along with pain in the sole region. This condition is called 'tarsal tunnel syndrome'.

MUSCLES OF THE POSTERIOR COMPARTMENT

The muscles of the posterior compartment are (from superficial to deep) (FIg. 28.3):

- Gastrocnemius
- Soleus
- Plantaris
- Popliteus
- Flexor hallucis longus
- Flexor digitorum longus
- Tibialis posterior.

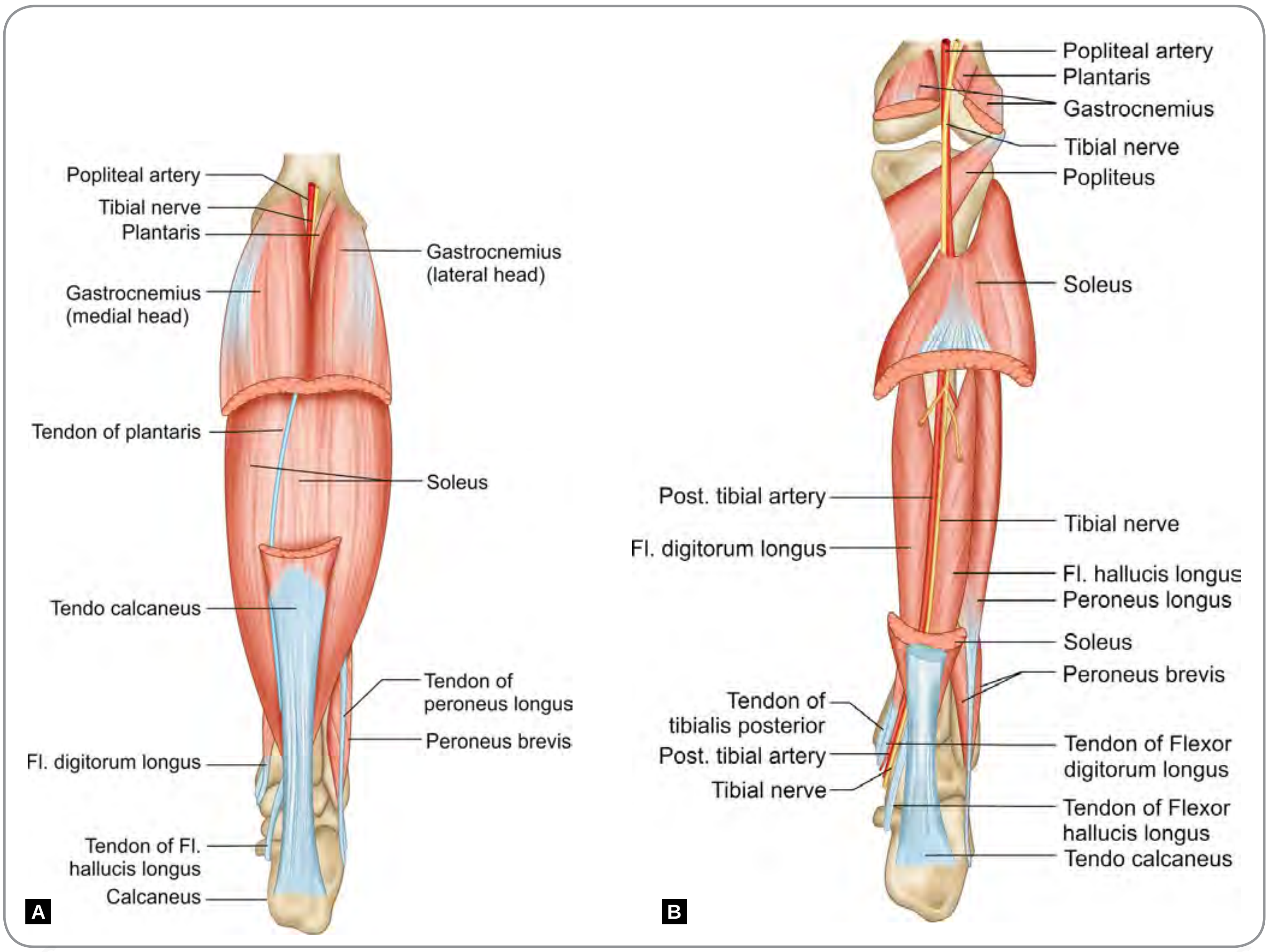
Table 28.1: Muscles of the back of the leg

Muscle	Origin	Insertion	Action	Nerve supply
Gastrocnemius (Fig. 28.4)	• Medial head: – Posterior aspect of medial condyle of femur – Adjoining part of posterior surface • Lateral head: Lateral surface of lateral condyle of femur	Through tendocalcaneus into middle of posterior surface of calcaneus	• Strong plantar flexion of foot (in walking, running, jumping) • Helps in flexion of knee joint • Steadies leg on foot	Tibial nerve (S1, 2)
Plantaris (Fig. 28.5)	Lower part of lateral supracondylar line of femur	Long thin tendon which is attached to medial margin of tendocalcaneus	Similar to above but action is very weak	Tibial nerve (S1, 2)
Soleus (Fig. 28.5)	• Posterior aspect of head of fibula • Posterior surface of fibula (upper 1/4) • Fibrous band connecting tibia and fibula • Soleal line of tibia • Middle one third of medial border of tibia	Through tendocalcaneus into middle of posterior surface of calcaneus	Same as gastrocnemius	Tibial nerve (S1, 2)
Popliteus (Fig. 28.6)	• Lateral condyle of tibia (from anterior part of groove) • Some fibres arise from the lateral meniscus of the knee joint	Posterior surface of shaft of tibia (triangular area)	• Rotates the tibia medially on the femur (when the leg is off the ground) • When the leg is on the ground (fixing the tibia), it rotates the femur laterally on the tibia. This unlocks the knee joint (at beginning of flexion)	Tibial nerve (L4, 5, S1)
			• It pulls the lateral meniscus backwards during lateral rotation of the femur (preventing injury to the meniscus)	
Flexor hallucis longus	• Posterior surface of fibula • Lowest part of interosseous membrane (Fig. 28.7)	• Tendon runs down over lower part of tibia, and behind talus • It turns forwards below the sustentaculumtali (on calcaneus) into the sole • Attached to base of distal phalanx of great toe (plantar aspect) (Fig. 28.2)	• Flexion of distal phalanx of great toe • Plantar flexion of foot • Maintains longitudinal arch of foot	Tibial nerve (S2, 3)

contd...

contd...

Muscle	Origin	Insertion	Action	Nerve supply
Flexor digitorum longus	Posterior surface of shaft of tibia	• Tendon passes behind medial malleolus and then on medial side of talus • In the sole, the tendon divides into four slips, one each for 2nd, 3rd, 4th and 5th digits • Each slip is attached to base of distal phalanx of the digit concerned (plantar aspect)	• Plantar flexion of distal phalanges • Continued action causes plantar flexion of other phalanges, and of the foot • Helps to maintain longitudinal arch of foot	Tibial nerve (S2, 3)
Tibialis posterior (Fig. 28.10)	• Posterior surface of shaft of tibia (upper two-thirds, below soleal line) • Posterior surface of fibula (upper two-thirds of medial part) • Interosseous membrane	• Main insertion into tuberosity of navicular bone • Slips to various tarsal and metatarsal bones (bases)	• Inversion of foot • Helps to maintain longitudinal arch of foot	Tibial nerve (L4, 5)



Figs 28.3A and B: Back of leg **A.** A segment of the gastrocnemius has been removed to expose deeper structures **B.** The gastrocnemius has been completely removed and a segment of the soleus has been cut away

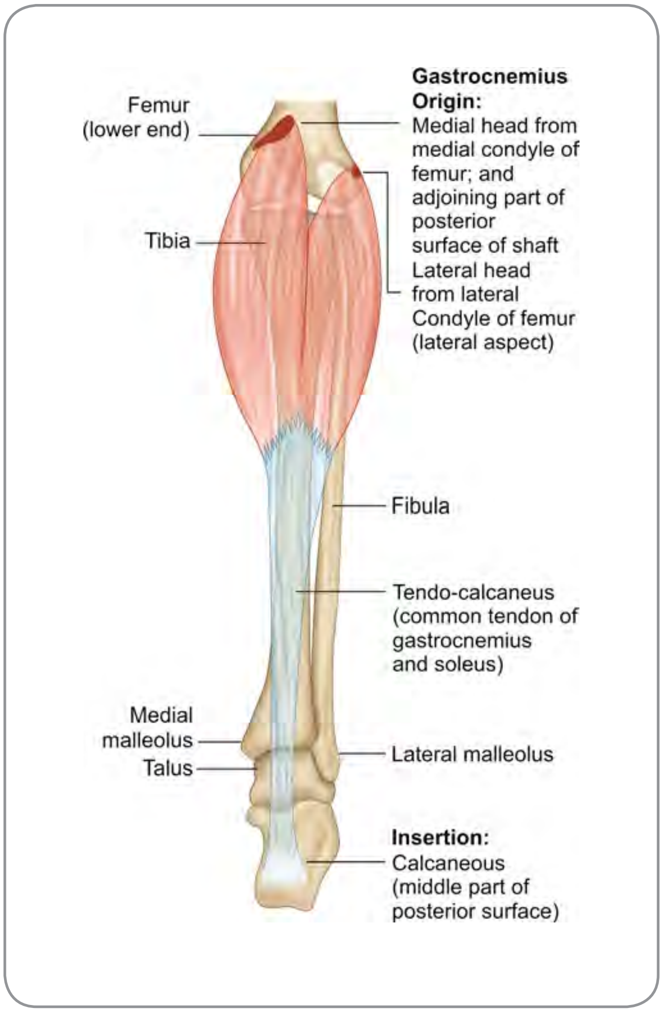


Fig. 28.4: Attachments of the gastrocnemius

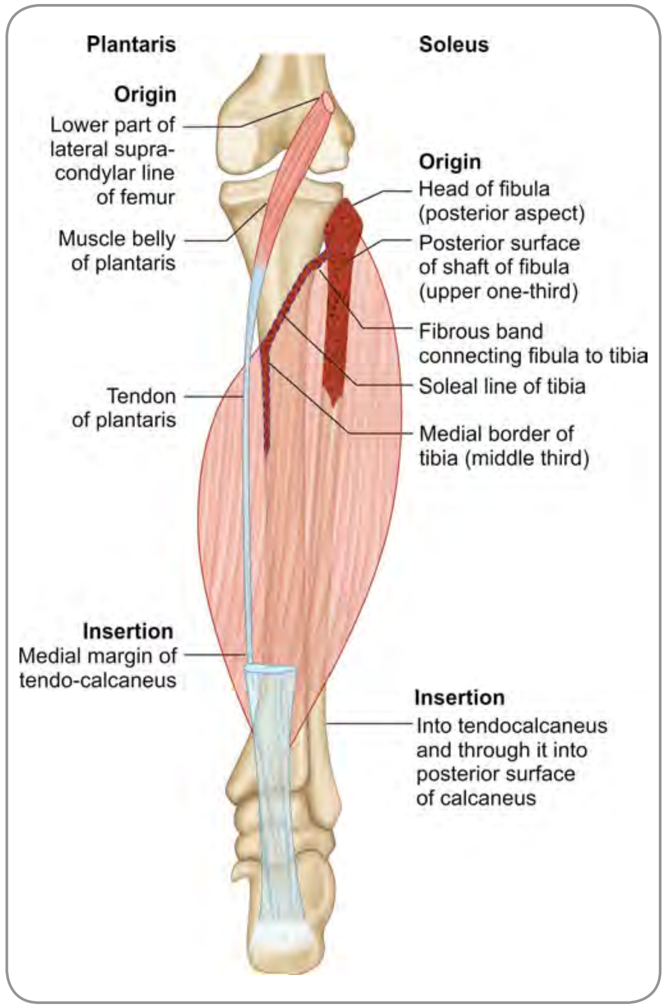


Fig. 28.5: Attachment of the soleus and of the plantaris

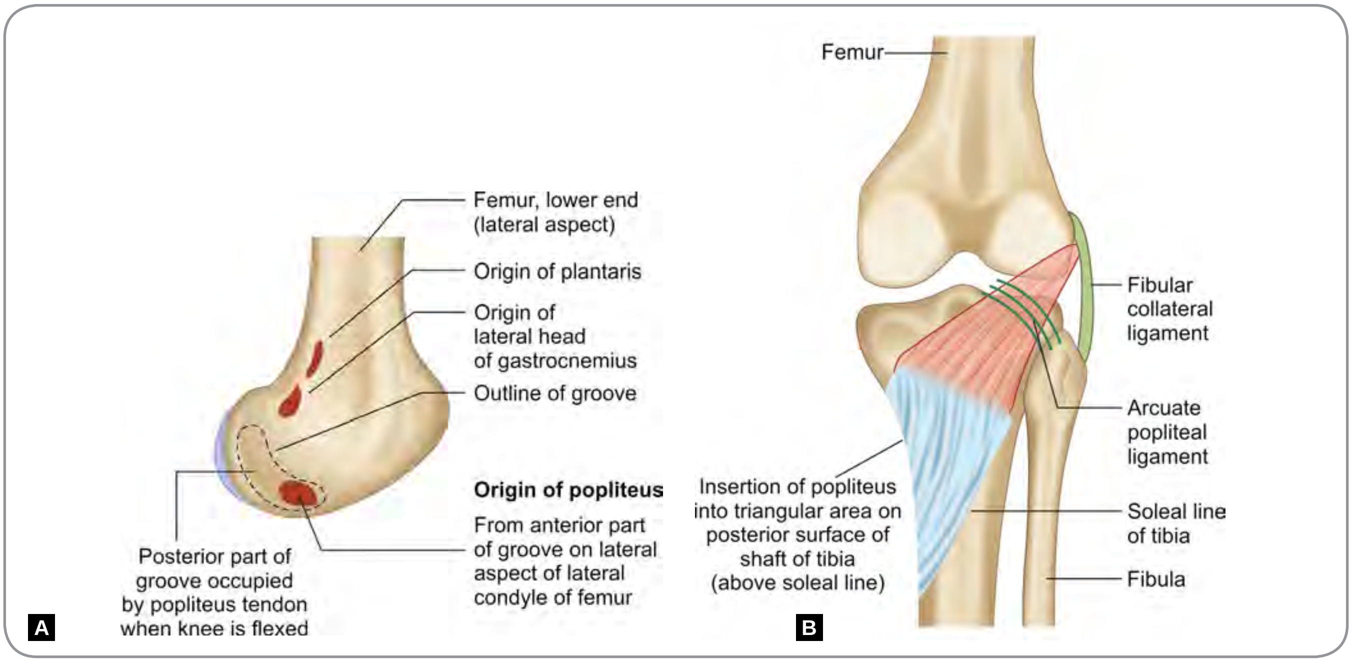
Additional Notes on the Superficial Muscles of Calf

- The gastrocnemius and the soleus are together called the ***triceps surae***. They are amongst the most powerful muscles of the body. By pulling on the calcaneus, they produce plantar flexion of the foot, and provide the propulsive force for walking, running and jumping.
- The ***tendocalcaneus*** (or calcaneal tendon or the ***Achilles tendon***; named after the Greek warrior who was vulnerable only in the heel) is the common tendon of insertion of both the gastrocnemius and the soleus (and the plantaris too). It is the strongest tendon in the body. The integrity of this tendon is very important in walking.
- Due to the common tendon of insertion, the gastrocnemii and the soleus are together referred to as the ***gastrosoleus***.
- The uppermost parts of the medial and lateral heads of the gastrocnemius (Greek.gaster=belly, kneme=leg; the ***belly of the leg*** from the shape of the bulge of the calf) form the boundaries of the lower part of the popliteal fossa, where they are overlapped by the tendons of the hamstring muscles. Except for this, the rest of the gastrocnemius is superficial.
- The soleus is a very powerful, multipennate muscle named after its shape that resembles the broad soles of animals (Latin.solum=ground, solea=undersurface of foot).
- The popliteal vessels and the tibial nerve pass deep to the fibrous band (between the fibula and the tibia) from which the soleus takes origin.
- Though both gastrocnemius and soleus cause plantarflexion at the ankle, gastrocnemius cannot act on the ankle when the knee is flexed (because the gastrocnemius originates from the femur, during flexion of knee,it cannot get fixed and build up pulling force). In a flexed knee, soleus alone causes plantarflexion.
- During propulsive movements of walking and running, gastrocnemius is more active than soleus.

- The soleus is more of a postural muscle; it is composed of red muscle with slow-acting, fatigue-resistant fibres. During standing, the constant pull of soleus keeps up the posture; otherwise the body would fall forward.
- The gastrocnemius and the soleus together produce the ***calf muscle pump*** (other names being skeletal muscle pump, tricipital pump, sural pump). As they contract, they help in the venous return from the lower limbs. However, due to its sustained and prolonged action, the soleus is often called the ***peripheral heart***. The muscle has very large venous sinuses within its substance; these sinuses are connected to the superficial and deep veins through the perforating veins which pass through the muscle. As the muscle contracts and maintains itself in a contracted state, the sinuses and perforating veins are compressed causing blood to flow into the superficial and deep systems.
- The muscles of the calf act together to maintain the erect posture because the line of gravity passes in front of the ankle joint. Erect posture and bipedal gait have been responsible for the large size of the gastrosoleus.
- A sesamoid bone may be found in the tendon of origin of the lateral head of gastrocnemius; it is called ***'fabella'***.
- Soleus counteracts the weight of the body and provides the propulsive force for walking to commence. Once walking movements are set, gastrocnemius acts quickly and increases the speed of walking
- In some lower animals, the tendon of gastrocnemius extends till the tarsal bones. In humans, due to the erect posture and weight balance, the muscle came to be attached to the calcaneus and the remaining part of the tendon metamorphosed into the long plantar ligament Similarly, soleus, which extended till the digits, became bulkier and stopped at the calcaneus. Flexor digitorum brevis muscle is considered to be the remnant of the distal part of soleus. Therefore, soleus and the flexor digitorum brevis together are the homologues of the flexor digitorum superficialis of the forearm.
- The soleus is absent in horses and dogs. It is present in cats but is less bulky. The bulkiness and strength of soleus in humans is well correlated with the plantigrade nature (walking and standing on feet). Plantar flexion in a plantigrade situation requires more efforts and hence a larger and stronger muscle. In digitigrade (walking on toes like dogs and cats) and unguligrade (walking on hoofs or the toe-tips like the horses and cattle) animals, forceful plantar flexion is not required and hence a weak (in cats) or absent soleus.

Clinical Correlation

- Tapping the tendocalcaneus leads to reflex contraction of the calf muscles, and plantar flexion of the foot. This is referred to as the ***ankle jerk*** (or the ***Achilles tendon reflex***).
- A bursa between the tendocalcaneus and the upper part of the calcaneus may get inflamed (***bursitis***) due to repeated irritation (e.g., in long-distance runners).
- Apart from enlargement of the naturally occurring bursae, constant friction can give rise to the formation of ***adventitial bursae***. Such a bursa may form over the tendocalcaneus in a person wearing badly fitting shoes.
- In violent exercise or during sports, the tendocalcaneus might rupture or may undergo inflammation. This leads to tendonitis, usually called ***Achilles tendonitis***.
- ***Rupture*** of the tendocalcaneus leads to loss of plantar flexion of the foot, and consequent inability to walk. The tendon can be repaired using fascia lata.
- ***Tear*** or ***avulsion*** of the medial head of gastrocnemius at its origin occurs due to over or unaccustomed stretching or repetitive contraction-relaxation of the muscle. There is an excruciating pain in the calf and the condition is called ***tennis leg***. There may be associated tear or injury to the plantaris or soleus. Movements at the ankle are restricted or painful; trying to stand on tip toes adds to the pain. Bruising or redness or swelling in the upper calf region is noted. Isolated tear of plantaris also causes symptoms of tennis leg.
- The tendon of plantaris is very long and is used in tendon grafting procedures.
- The massiveness of the calf is unique and peculiar to humans and is due to the erect posture in normal standing and also in walking, running and other locomotory movements.
- As much as the gastrocnemius is a powerful plantar flexor, it relaxes during dorsiflexion. This relaxation is jeopardised by wearing high-heeled shoes. Continuous wearing of high heels makes the gastrocnemius (and the soleus to a lesser extent) contract more to keep the leg erect during walking. The muscle gets accustomed to this additional contraction and is not able to extend (or relax) as much as it did before getting so accustomed. This leads to what is called the ***ligamentous action*** of the gastrocnemius (the muscle functioning as a restraining ligament on the ankle), in turn, leading to incomplete dorsiflexion during flat-surface walking and other movements. To compensate for the loss, additional dorsiflexion is achieved by the involvement of the talocalcaneonavicular joint, where secondary dorsiflex on (movement that is seen only in compromised situations) occurs around an oblique axis; as a result, the distal part of the foot moves dorsally and laterally, causing the medial border of the foot to get depressed. The individual, if required to walk without heels and/or on flats, experiences discomfort and walks out-toed (toes pointing laterally); the medial longitudinal arch flattens out and flat foot occurs.
- Long hours of immobilisation of the calf muscles, especially in older persons, can lead to stagnation of blood and thrombosis of the soleal venous sinuses. Dislodging of the thrombus may cause embolism. It is necessary to keep the calf muscles active.



Figs 28.6A and B: **A** Lateral aspect of lower end of femur to show area for origin of popliteus **B.** Posterior aspect of the bones of the popliteal region showing the insertion of popliteus

Additional Notes on Plantaris

- The muscle belly, which is only a few centimetres long, ends in a long thin tendon that runs downwards between the gastrocnemius and the soleus (and usually merges with tendocalcaneus).
- The plantaris is a vestigial remnant of a large muscle that was originally attached, below, to the plantar aponeurosis (comparable with the Palmaris longus). Due to its small size it is of little functional importance
- Its long and thin tendon may be mistaken for a nerve by a fresh student doing dissection and hence the tendon is often dubbed ***the freshman's nerve***.

Additional Notes on Popliteus

- The muscle arises, by a tendon, from the lateral aspect of the lateral condyle of the femur. There is a prominent groove on the lateral surface of the lateral condyle of femur called the ***popliteal groove***. The popliteus takes origin from the anterior part of this groove. The posterior part of the groove is occupied by the popliteus tendon in full flexion at the knee.
- The origin lies within the capsule of the knee joint (intracapsular) It is covered by the fibular collateral ligament and by the biceps tendon. A few fibres also originate from the back of lateral meniscus.
- The muscle emerges from the knee joint through an aperture in the capsule. The superficial margin of this aperture is formed by the ***arcuate popliteal ligament***, which also gives origin to some fibres of the muscle.

Development

Popliteus belongs to the flexor-pronator muscle mass of the lower (hind) limb. It is considered the lower equivalent of the pronator teres. In a situation where the leg would have to be pronated, the muscle would stretch between the fibular styloid and upper posterior tibia and cause pronation. However, complete pronation of leg was never required in evolution. As the vertebrate evolution progressed, amphibians and lower reptiles developed jumping skills; to withstand the jumping impact, bones of the leg coalesced to form a unified tibiofibula and the popliteus regressed or did not develop. With further evolution, the hind limb was thrusted with locomotor and weight-bearing responsibilities. Therefore, complete pronation and its consequent grasp functions were never required. With increased weight-bearing capabilities, the femoral and tibial condyles became larger. The fibula, which was articulating with the lateral femoral area ti l the level of higher reptiles, was displaced distally due to enlargement of the lateral tibial condyle. The popliteus muscle, which originated from the fibular styloid, passed behind the femorofibular joint and the lateral tibiofemoral joint. As the fibula moved distally, the popliteus acquired a femoral attachment. The femorofibular meniscus got incorporated as the tendon of popliteus. In the humans, the tendon of popliteus arises from the popliteal groove on the lateral surface of the lateral femoral condyle. The tendon is intra-articular (remnant of the femorofibular meniscus which is intra-articular) and emerges out of the joint capsule. The muscular portion that continues from the tendon expands to get inserted into the tibia. The muscle retains its rotational control property, medial rotation of tibia being akin to pronation (the preaxial border rotating medial).

contd...

Development *contd...*

It has been proposed by some authors that the popliteus muscle had migrated from a lower level to its present position. The course of the nerve to popliteus (first on the posterior surface, winding around the inferior border and then coursing on the anterior surface to enter the muscle) is cited as evidence. The muscle is supposed to have undergone an upside down turn as it migrated. However, embryological and evolutionary evidences for such a migration are lacking.

- The major role played by the popliteus in humans is to facilitate movements at the knee joint and maintain the joint's stability. The action of the muscle causing lateral rotation of the femur on the tibia and medial rotation of the tibia on the femur comes into play in standing, walking and running (specially on uneven surfaces) and all positions where flexion-extension of knee occur. Thus, ***popliteus is the key rotational control muscle of the lower limb***.
- Several small additional muscles in the region of the popliteus have been seen; these are collectively called the ***accessory popliteal muscles***. The accessory muscles include the popliteus minor (arises from femur immediately medial to plantaris origin and inserts to posterior part of knee joint capsule) and the peroneotibialis (arises from head of fibula and inserts to upper end of soleal line – lies underneath popliteus).
- ***Cyamella*** is a small sesamoid bone seen within the tendon of popliteus.

Clinical Correlation

The lateral meniscus of the knee joint lies deep to the tendon of origin of the popliteus. Some fibres of the muscle take origin from this meniscus. Due to its attachment to the lateral meniscus, the popliteus pulls the meniscus backwards during lateral rotation of the femur. This prevents injury to the meniscus.

Additional Notes on the Long Flexors

- The tendon of flexor hallucis longus turns forwards below the sustentaculum tali that serves as a pulley for it. As the tendon lies on the medial side of the calcaneus, it runs deep to the flexor retinaculum (Fig. 28.2) and is surrounded by a synovial sheath. It passes above (i.e., deep to) the tendon of the flexor digitorum longus.
- The flexor digitorum longus muscle ends in a tendon that passes behind the medial malleolus where the tendon is covered by the flexor retinaculum and is surrounded by a synovial sheath The tendon runs down the lateral side of the talus and passes above the sustentaculum tali. It then turns laterally to enter the sole of the foot (Fig. 28.8). As it does so, it crosses below (i.e., superficial to) the tendon of the flexor hallucis longus, which separates it from the plantar calcaneonavicular (spring) ligament.
- When the tendons of the two long flexors cross in the sole, the flexor hallucis gives a slip to flexor digitorum

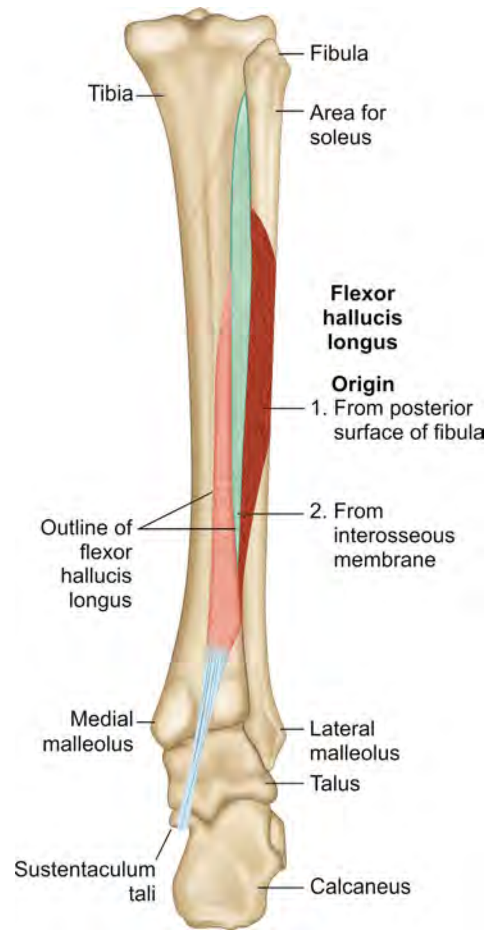


Fig 28.7: Scheme to show the flexor hallucis longus muscle and its origin

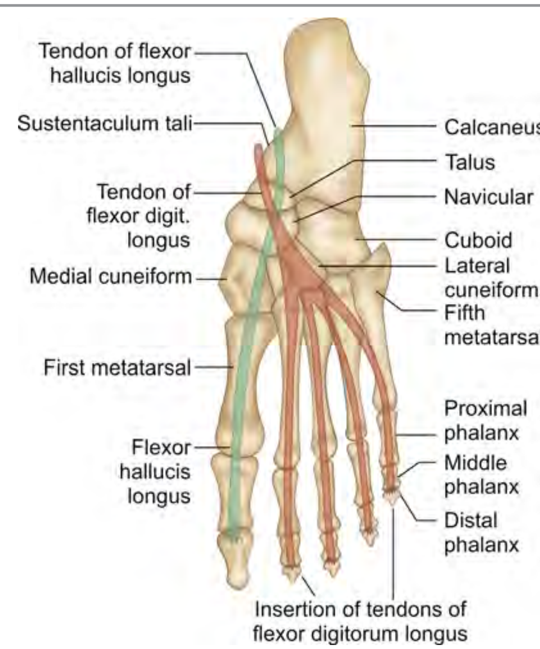


Fig. 28.8: Course and attachments of tendons of flexor hallucis longus and flexor digitorum longus in the sole

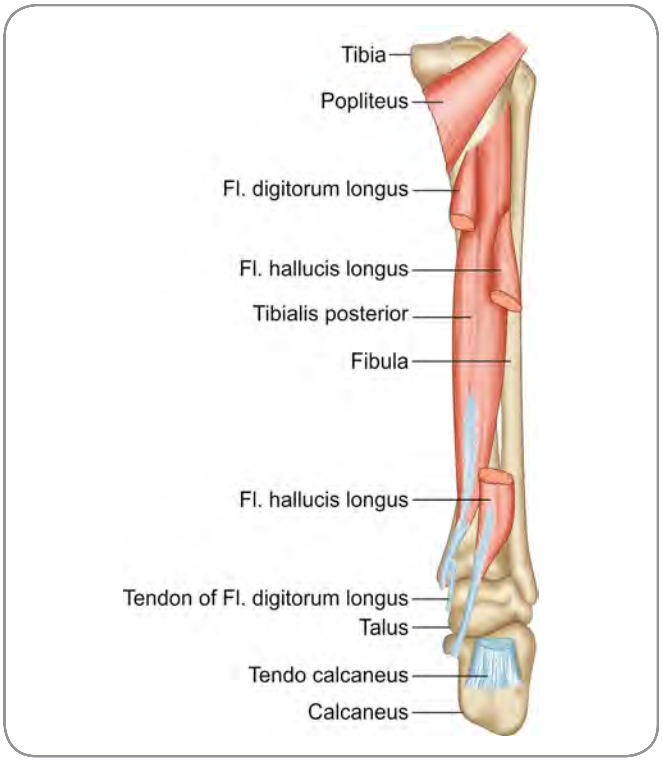
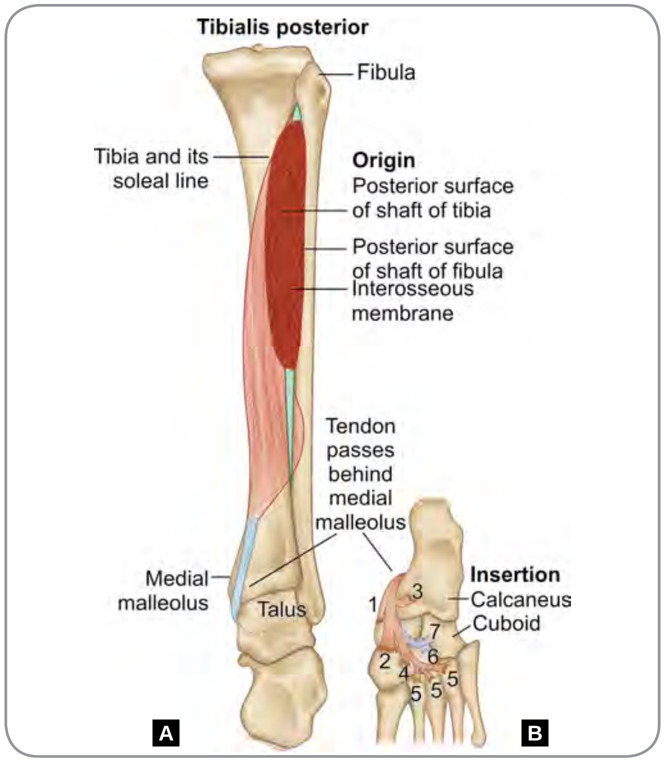


Fig. 28.9: Back of the leg showing deep muscles



Figs 28.10A and B: A. The tibialis posterior muscle and its origin **B.** Skeleton of foot seen from below to show insertion of tibialis posterior

that passes into the tendons which go to the second and third toes. This is the ***William Turner's slip*** (or simply the Turner's slip, named after the English anatomist Sir William Turner). The slip provides additional strength to the flexor digitorum longus. By virtue of the Turner's slip running to the second and third toes, the flexor hallucis longus, in a way coordinates flexion of the medial three toes which are components of the medial longitudinal arch

- The tendon of flexor digitorum longus, due to its position from medial to lateral in the sole, has a lateral obliquity. The consequent pull on the toes when the muscle contracts will tend to cause a medial deviation. The flexor accessorius muscle (one of the small muscles of the sole) gets inserted to the lateral side of the tendon. This straightens the line of pull.

Additional Notes on Tibialis Posterior

- The tibialis posterior, the deepest muscle in posterior leg (Fig. 28.9), ends in a tendon that passes behind the medial malleolus; and then deep to the flexor retinaculum to reach the sole of the foot.
- The tendon divides into a number of slips and, thus, has multiple insertions.
  - The main slip is inserted into the tuberosity of the navicular bone and into the medial cuneiform bone (1 and 2 in Fig. 28.10B).

  Other slips are inserted into:
  - the sustentaculum tali of the calcaneus (3 in Fig. 28.10B)
  - the intermediate cuneiform (4 in Fig. 28.10B)
  - the bases of the 2nd, 3rd and 4th metatarsals (5 in Fig. 28.10B)
  - Occasionally, some slips may reach the lateral cuneiform and cuboid bones (6 and 7 in Fig. 28.10B).

Synovial Sheaths of the Tendons of the Deep Muscles of Leg (Fig. 28.11)

The three tendons passing deep to the flexor retinaculum, namely the tendons of tibialis posterior, flexor hallucis longus and flexor digitorum longus are surrounded by

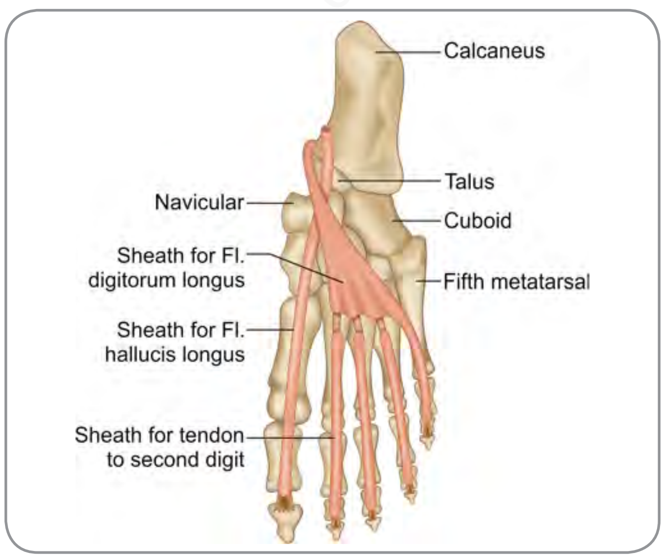


Fig. 28.11: Synovial sheaths related to tendons of flexor muscles of the back of the leg as seen in the sole

synovial sheaths which extend for some distance proximal to the retinaculum. Their distal extent is variable. The sheath of tibialis posterior begins about 5 cm above the medial malleolus and extends almost to the insertion of the muscle. The sheath of flexor hallucis longus begins a little below the sheath of tibialis posterior, and may end near the base of the first metatarsal, or may extend right up to the insertion into the terminal phalanx. The sheath of flexor digitorum longus begins immediately below the sheath of tibialis posterior and may end near the navicular bone; or may expand to enclose the proximal parts of the tendons for the digits. The distal parts of the tendons for the 2nd, 3rd and 4th digits have independent synovial sheaths, which facilitate their movement through osseo-aponeurotic canals. The 5th digit has a similar sheath that is continuous proximally with the sheath for the tendon of the flexor digitorum longus.

ARTERIES OF THE POSTERIOR COMPARTMENT OF LEG

Posterior Tibial Artery

Course and Relations (Fig. 28.12)

The posterior tibial artery is the larger of the two terminal branches of the popliteal artery. It, therefore, begins in the upper part of the back of the leg, at the lower border of the popliteus muscle. The artery descends in the back

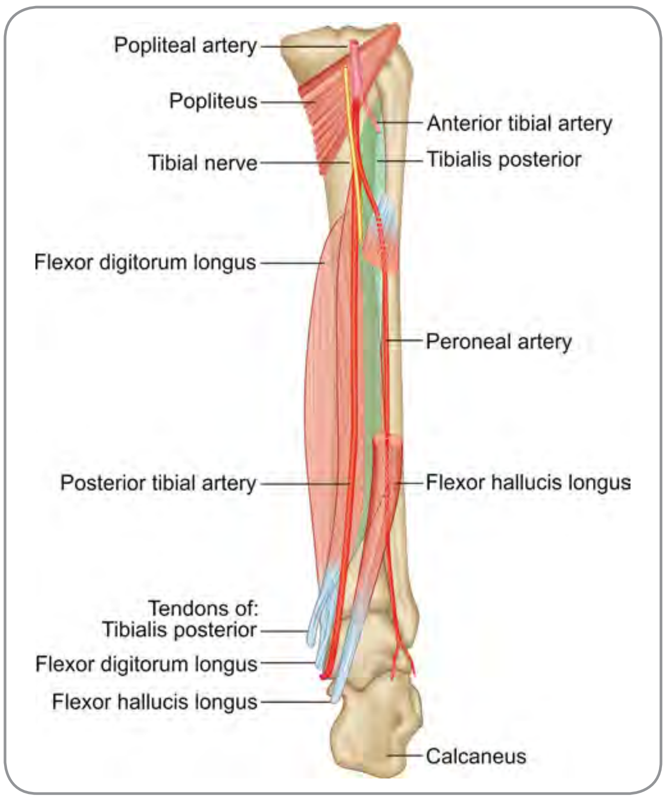


Fig. 28.12: Course and relations of posterior tibial and peroneal arteries

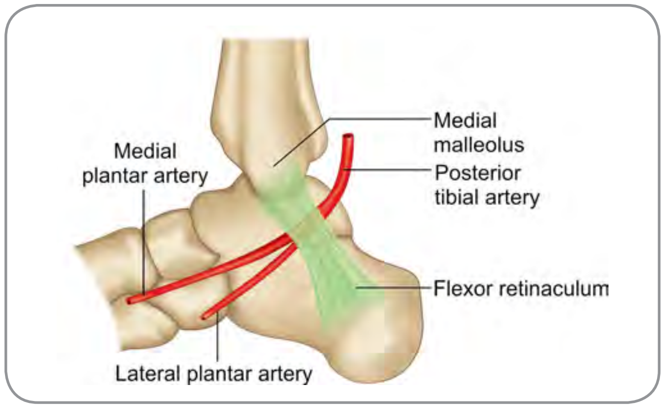


Fig. 28.13: Relationship of posterior tibial artery to the flexor retinaculum

of the leg, passing medially as it does so. It terminates by dividing into the medial and lateral plantar arteries, under cover of the flexor retinaculum, on the posteromedial side of the ankle, midway between the medial malleolus and the medial tubercle of the calcaneus (Fig. 28.13).

In the posterior compartment, it is separated from the superficial muscles of the calf by the superficial transverse septum. However, in the distal part, as it curves medially, it is superficial and is covered only by skin and fasciae. The terminal part of the artery is deep to the flexor retinaculum and abductor hallucis. Anterior to the artery (or deep to it) there are (from above downwards): (1) tibialis posterior and the deep transverse septum, (2) flexor digitorum longus, (3) posterior aspect of the tibia, and (4) ankle joint.

At the level of the ankle, the artery is separated from the medial malleolus by the tendons of tibialis posterior and the flexor digitorum longus. The tendon of flexor hallucis longus lies posterolateral to it.

The artery is accompanied by the tibial nerve. The nerve is at first medial to the upper end of the artery, but it soon crosses behind the artery and comes to lie on its lateral side. The venae comitantes accompany the artery throughout its length.

Branches (Fig. 28.14)

The branches of the posterior tibial artery are:

- ***The circumflex fibular branch:*** It runs through the substance of soleus and winds round the lateral side of the neck of the fibula to reach the front of the knee; it takes part in the genicular anastomosis.
- ***A nutrient artery to the tibia:*** It is given out immediately after the origin of the posterior tibial artery, pierces the tibialis posterior muscle and enters into the nutrient foramen of the bone on its posterior surface just below the soleal line.
- ***Peroneal artery:*** It is a large branch that arises close to the origin of the posterior tibial and forms an important content of the posterior compartment.

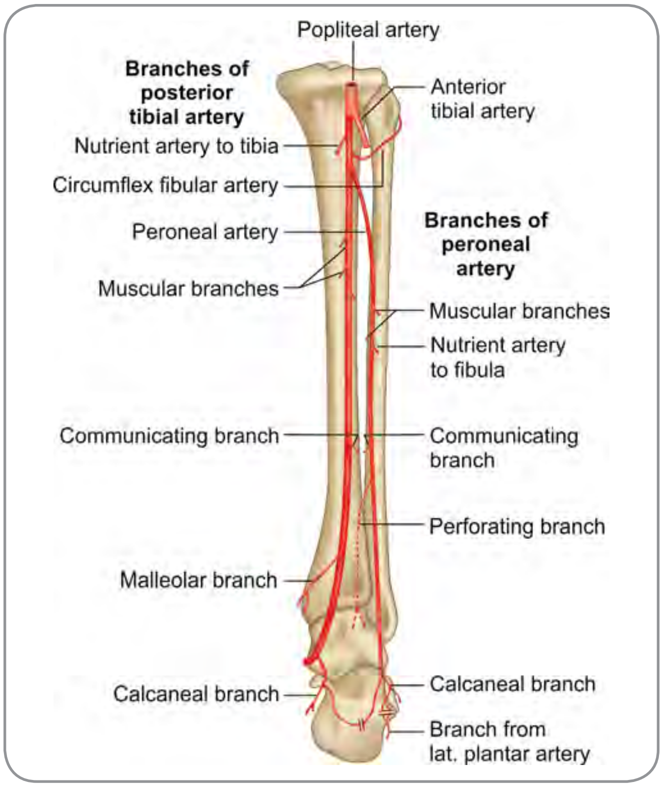


Fig. 28.14: Branches of posterior tibial and peroneal arteries

- ***Muscular branches*:** They are given out at various levels and supply the muscles of the region
- ***Cutaneous branches*:** Several of these are given out from the artery and supply the skin of the medial part of the leg.
- ***A communicating branch*:** It is given out in the lower leg and forms an arch with a similar branch of the peroneal artery, a few centimetres above the inferior tibiofibular joint.
- ***A (medial) malleolar branch*:** It is given out at the level of the malleolus and anastomoses with other arteries on the medial malleolus.
- ***(Medial) Calcaneal branches*:** They arise near the lower end of the artery, pierce the flexor retinaculum and supply tissues of the heel.

Surface Anatomy

A broad line from the lower angle of popliteal fossa at the level of neck of fibula to a point midway between the medial malleolus and the most prominent part of the heel indicates the posterior tibial artery on the surface.

Clinical Correlation

- ***Posterior tibial pulse*** can be felt behind and below the medial malleolus between the tendons of flexor digitorum longus and flexor hallucis longus. Palpation of the posterior

contd…

Clinical Correlation *contd…*

tibial pulse is facilitated by inversion of the foot (that relaxes the flexor retinaculum). Failure to feel the pulse can occur in some normal persons, but it is usually the effect of arterial obstruction. In arterial obstruction, the individual experiences intermittent claudication. This is characterized by pain in the calf muscles while walking, but disappearance of pain on rest. While walking, the muscles demand more blood supply; this demand is not met with and muscular ischaemia causes pain.
- ***Thromboangitis obliterans*** is a condition seen mostly in young men who are chronic smokers. Arteries of the leg are blocked and may result in gangrene of the toes, foot or leg
- When the dorsalis pedis is a branch of the peroneal artery, its pulse cannot be felt in the normal position.

Peroneal Artery

Course and Relations (Fig. 28.12)

The peroneal artery is the largest branch of the posterior tibial. It is given off from the posterior tibial near the upper end of the latter. It runs downwards on the back of the fibula, with the tibialis posterior in front and the flexor hallucis longus behind. It passes behind the inferior tibiofibular joint and then the lateral malleolus to reach the lateral aspect of the heel and the foot. It terminates by joining the rete calcaneum.

Branches (Fig. 28.14)

The branches of the peroneal artery are:

- ***Muscular branches:*** To the muscles of the region, specially the peroneal muscles.
- ***A nutrient artery:*** To the fibula.
- ***A communicating branch:*** Anastomoses with a corresponding branch from the posterior tibial artery and forms an arch a few centimetres above the inferior tibiofibular joint.
- ***Calcaneal branches*:** Supply the heel and anastomose with other arteries in the region.
- ***A perforating branch:*** Given out few centimetres proximal to the ankle, it passes through the lower part of the interosseous membrane to reach the anterior compartment of the leg. Here it anastomoses with other arteries in front of the ankle including the lateral tarsal branch of the dorsalis pedis artery. Sometimes, this anastomosis is so large that the dorsalis pedis appears to be a continuation of the peroneal artery (the perforating branch may even replace the dorsalis pedis artery).
- ***A malleolar branch:*** Runs to the lateral malleolus and anastomoses with arteries of the region.

VEINS OF THE POSTERIOR COMPARTMENT OF LEG

The veins of the posterior compartment deserve special treatment because of their important role in the venous return from the lower limbs (the posterior and anterior tibial veins are the deep veins of the leg).

Posterior Tibial Veins

The ***venae comitantes of the posterior tibial artery*** are otherwise called the posterior tibial veins. They lie one on each side of the artery; they are connected to each other by small channels which run across the artery The posterior tibial veins begin by the union of the venae comitantes of the medial and lateral plantar arteries They receive the muscular veins of the region, especially the ones which drain the venous networks in soleus and gastrocnemius. The posterior tibial veins are also connected to the superficial veins of the lower limb (the great and small saphenous veins) by perforating veins. These perforators have valves which permit flow from the superficial to the deep veins.

The posterior and anterior tibial veins (venae comitantes of the anterior tibial artery) unite at the inferior border of popliteus to form the popliteal vein.

Clinical Correlation

- When the lower limbs are immobilised for a considerable period of time (disease or post-surgery), the deep veins may get thrombosed. Apart from impeding the venous return and leading to complications, the thrombus may get detached and produce emboli (singular, embolus). If the emboli reach the pulmonary circulation, they may become fatal.

NERVE OF THE POSTERIOR COMPARTMENT OF LEG

Tibial Nerve

The tibial nerve from the popliteal fossa descends down and at the inferior border of popliteus becomes the nerve of the posterior compartment. The nerve enters the posterior compartment along with the posterior tibial vessels deep to the tendinous arch of origin of soleus muscle. It runs through the posterior compartment in close relation to the vessels. Under cover of the flexor retinaculum, it divides into its two terminal divisions, namely the medial plantar and the lateral plantar nerves.

Course and Relations

Throughout its course in the posterior compartment, it is separated from the gastrocnemius and soleus by the superficial transverse septum. In fact, the nerve is very closely applied to the deep surface of this septum. Under cover of the fibrous arch of soleus, the nerve is medial to the posterior tibial artery. Then it crosses the artery (and the accompanying venae comitantes) posteriorly from medial to lateral (Fig. 28.12). At the level of the ankle, the nerve is lateral to the artery, and lies between the tendons of flexor digitorum longus (above and medial) and the flexor hallucis longus (below and lateral). Under cover of the flexor retinaculum where the nerve is not covered by any muscle, it may be palpated through the retinaculum.

Branches in the Leg

The branches of the tibial nerve in the leg are:

- ***Muscular branches:*** Usually four in number, the soleus (entering the muscle on its deep surface), the tibialis posterior (arising often by a common trunk with the soleal branch), the flexor digitorum longus, and the flexor hallucis longus (the last branch usually supplies a twig to the peroneal artery – vasa nervorum).
- ***Cutaneous branches:*** One or two branches, also called the medial calcaneal branches, which pierce the flexor retinaculum to supply the skin and fascia of heel.
- ***Articular branches:*** One or two, to the ankle joint.
- In addition to the above, a medullary branch to the fibula is also given out; the two terminal branches of the tibial nerve are also given out in the leg.

SOLE OF FOOT

Sole is the undersurface of the foot; it bears the weight of the body and hence is subjected to severe pressure. The skin of the sole is thickened to withstand this pressure. The subcutaneous tissue is loaded with fat; this is more in locations where the foot comes in more contact with the ground. Such locations are the heel, the heads of the metatarsals and the tips of the toes. Thin fibrous septa run between the skin and the deep fascia; these septa separate the fat into small loculi.

Sole of foot is the homologue of the palm of hand. However, unlike the hand which is an organ of grip and prehension, the foot is an organ of support and locomotion. The great toe has lost its prehensile power and the other toes are reduced in size. These changes help in maintenance of the body's balance

The deep fascia of the sole is a continuous sheet that joins the fascia of the dorsum at the borders of the foot. Also called the plantar fascia, the deep fascia is thickened and forms the plantar aponeurosis.

Dissection

In the dissection theatre:

Make a curved horizontal incision on the distal part of heel. Make another horizontal incision parallel and posterior to the skin crease between the sole and the toes. Make a longitudinal incision in the middle of the sole to join the two horizontal incisions. Reflect the skin flaps medially and laterally. The skin is thick and hence it requires some efforts to reflect properly Observe the superficial fascia which is laden with fat specially at the heel. Clean the fat piecemeal and study cutaneous nerves and vessels.

Clean the superficial fascia to expose the plantar aponeurosis. Define the central, medial and lateral parts of the aponeurosis; trace the central part distally and note that it splits into five.

Make a longitudinal skin incision on the plantar surface of big toe and either the second or third toe As you reflect the skin, you will be able to see the plantar digital vessels and nerves. Also note that the deep fascia has condensed to form the fibrous flexor sheath. Trace the slip of plantar aponeurosis to the fibrous flexor sheath.

Cut the plantar aponeurosis transversely, anterior to the heel. Move the cut ends aside. See the underlying muscles. Clean up the first layer of muscles. Locate the medial and plantar nerves. Find the plantar digital nerves in the toes and trace some of them backward to the medial or lateral plantar nerves. Identify the tendinous slips of flexor digitorum brevis and follow them to the toes; cut one or two of the fibrous flexor sheaths to trace these tendons to their insertions. Cut across the abductor hallucis and flexor digitorum brevis and reflect the cut parts. Identify the medial and lateral plantar arteries and trace their branches. Clean up the fascia around the neurovascular structures; try to establish the continuity of the small vessels and nerve twigs with their parental trunks. Locate the long flexor tendons and define them. See their curvatures, crossing and also the Turner's slip.

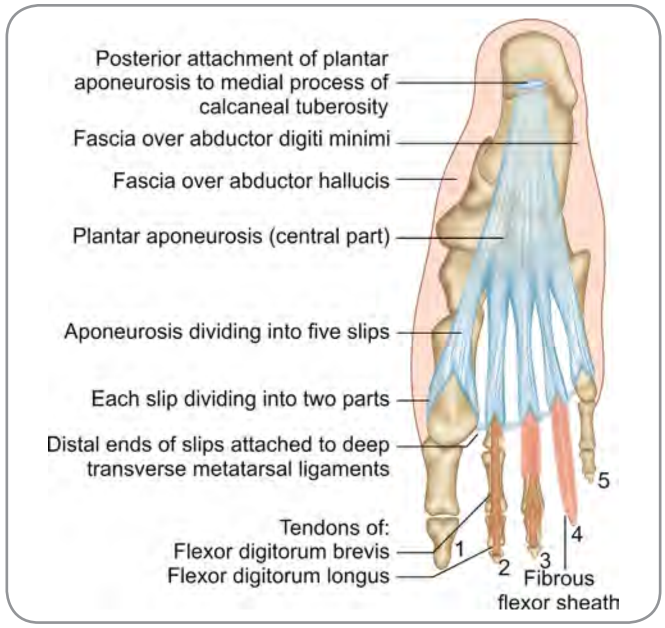


Fig. 28.15: Plantar aponeurosis

PLANTAR APONEUROSIS (FIG. 28.15)

The ***plantar aponeurosis*** is extremely strong due to the dense arrangement of its component fibres. It consists of central, medial and lateral parts. The medial and lateral parts are relatively thin. They cover the abductor hallucis and the abductor digiti minimi respectively.

Central Part and Attachments

The central part is thick and strong (some authors refer to the central part alone as the plantar aponeurosis). It overlies the flexor digitorum brevis. It is triangular in shape with a posterior apex and an anterior base. The apex is attached to the medial process of the calcaneal tuberosity. The densely packed longitudinal fibres fan out as they proceed forward. The base or the anterior end of the central part, just proximal to the metatarsal heads, splits into five slips; one slip proceeds to each toe. Near the head of the corresponding metatarsal bone, each slip divides into a superficial and a deep stratum. The superficial stratum merges with the superficial transverse metatarsal ligament and also sends a few fibres to the skin furrow between the sole and the toe. The deep stratum further splits into two, a medial and a lateral process. The two processes pass around the sides of the flexor tendons of the digit concerned and get attached to the deep transverse metatarsal ligaments and the plantar ligaments of the metatarsophalangeal joints. The distal end of the mid area of the deep stratum becomes continuous with the fibrous flexor sheath of the corresponding toe.

From the medial and lateral margins of the central part, thick and strong septa are sent upwards between the centrally placed flexor digitorum brevis and the two abductors on the sides (the abductor hallucis medially and the abductor digiti minimi laterally). These two septa give origin to fibres of the muscles between which they lie and merge with the fascia on the deep surface of the flexor brevis. Thus the flexor brevis is enclosed in a separate fascial compartment. Extensions from these two septa (which are also called the medial and the lateral intermuscular septa) get attached to the tarsal bones, fasciae over adjacent muscles and the first metatarsal bone on the medial aspect and the fifth metatarsal bone on the lateral aspect.

Functions of Plantar Aponeurosis

- It provides protection to the underlying structures.
- It helps in the maintenance of the longitudinal arches of the foot. When the toes are dorsiflexed (or when the individual stands on toes), the proximal phalanx pulls on the slip of the aponeurosis; the slip then winds around the head of the concerned metatarsal; this causes the posterior pillar of the longitudinal arch

to move forwards and therefore raises the arch. This phenomenon is called the '***windlass effect***'.

Clinical Correlation

- Chronic inflammation of plantar aponeurosis may occur. The condition is called plantar fasciitis. It commonly affects the posterior bony attachment more and causes pain in the heel. People who stand for long periods of time are affected.
- Constant pressure at the heel associated with rapid and jerky movements can cause the apex of the aponeurosis to tear or be avulsed from its attachment. Since it was initially noticed in policemen, this condition came to be called the '***policeman's heel***'.
- Ossification of the apex or parts of the aponeurosis can occur. Ossification of the posterior end of the aponeurosis leads to the formation of a projection from the calcaneus called the ***calcaneal spur***.
- The space deep to the plantar aponeurosis may get infected and an abscess formed (the deep plantar abscess). Pus can be drained by an incision parallel to the medial border of the foot.
- ***Bunion*** is an inflamed adventitial bursa over the head of the first metatarsal bone.

Fibrous Flexor Sheaths (Fig. 28.16)

The deep fascia of the toes is modified to form the fibrous flexor sheaths. The plantar deep fascia thickens and gets attached to the sides of the proximal and middle phalanges and distally to the base of the distal phalanx. At the two interphalangeal joints, the fascia merges with the sides of the joint capsules. This thickened fascia is called the ***fibrous flexor sheath*** (a fibrous sheath on the flexor aspect). Due to the attachments of the sheath, an osseofibrotic tunnel is formed; the deep or superior wall of the tunnel is formed of the phalanges and the joint capsules; the side walls and the superficial or inferior wall are formed of the fibrous flexor sheath itself. The flexor tendons of the toes run in the tunnel of their respective toes. The tunnel of the big toe has only the tendon of flexor hallucis longus. Each canal is lined by a synovial sheath providing lubrication for smooth movement of the tendons.

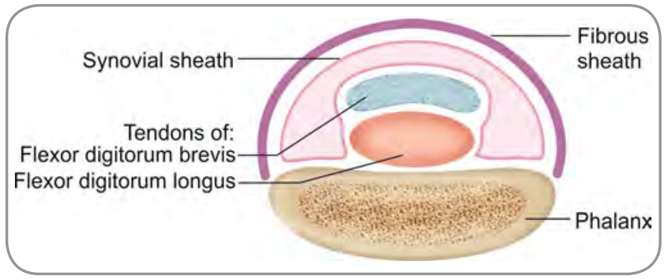


Fig. 28.16: TS across a digit to show the fibrous flexor sheath and the synovial sheath for flexor tendons

The fibrous flexor sheath, apart from providing protection to the flexor tendons, also restrains them during movements. Thus, displacement and bowstringing are prevented.

MUSCLES AND RELATED STRUCTURES OF SOLE

For the sake of description, the muscles and tendons of the sole are classified to be in four layers, from superficial to deep. The nerves and vessels are in the neurovascular planes. The first neurovascular plane is between the first and second muscular layers; the second neurovascular plane is between the third and fourth muscular layers.

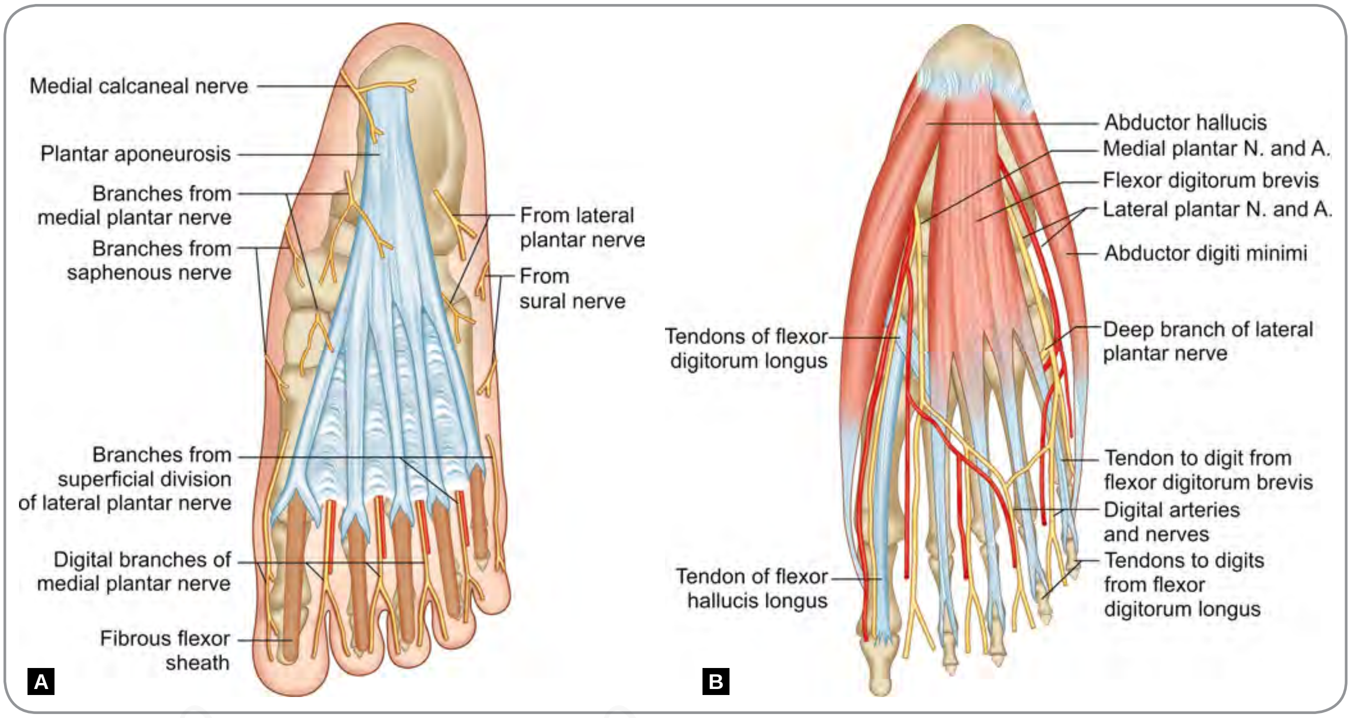
Main Function of Muscles in the Sole

Various muscles in the sole perform their respective movements. However, their collective main function is to stabilise the toes while walking. This is necessary as the propulsive force is transmitted to the ground through the toes.

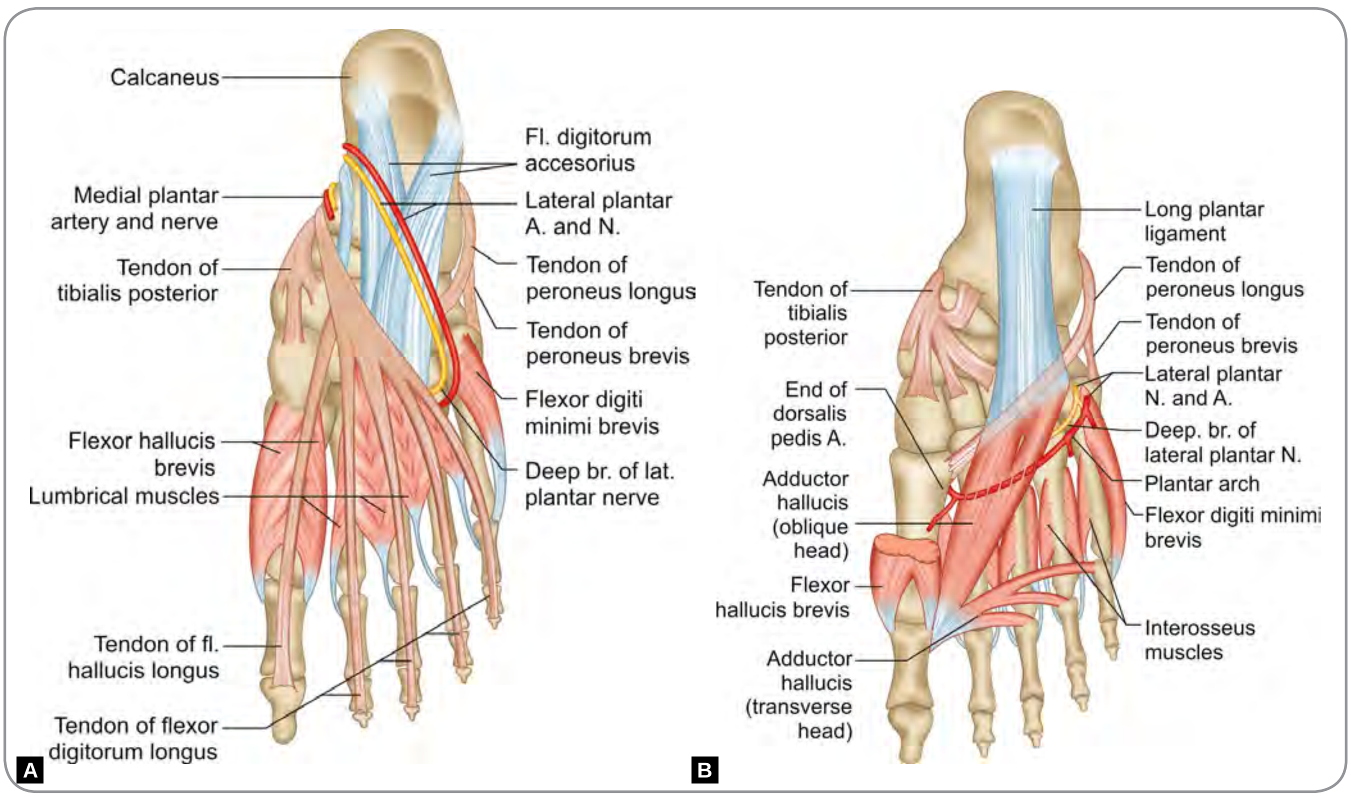
When a foot touches the ground (during walking), it first lands on the calcaneus. In the next phase both the anterior and posterior parts of the foot touch the ground. In the third phase, the calcaneus is lifted off the ground and the anterior part of the foot exerts strong propulsive pressure on the ground. During this phase, the toes need to be stabilised to avoid imbalance and falling down.

Table 28.2: Contents of the various layers of the sole

	Muscles	Tendons
First Layer	• Flexor digitorum brevis • Abductor hallucis • Abductor digiti minimi	
Second Layer	• Flexor digitorum accessorius (Quadratus plantae) • Lumbrical muscles	• Flexor hallucis longus • Flexor digitorum longus
Third Layer	• Flexor hallucis brevis • Flexor digiti minimi brevis • Adductor hallucis	
Fourth Layer	• Plantar interossei • Dorsal interossei	• Tibialis posterior • Peroneus longus



Figs 28.17A and B: Sole of foot **A.** Superficial structures **B.** Structures seen after removal of the plantar aponeurosis



Figs 28.18A and B: Sole of foot **A.** Structures seen at a deeper level than in Fig. 28.17B **B.** Structures at a deeper level than that shown in A

Table 28.3: Muscles of the first layer of the sole

	Flexor Digitorum Brevis (Fig. 28.19)	Abductor Hallucis (Fig. 28.21)	Abductor Digiti Minimi (Fig. 28.21)
Origin	Tuberosity of calcaneus (medial process)	• Tuberosity of calcaneus (medial process) • Flexor retinaculum • Some fibres from plantar aponeurosis (deep aspect)	• Tuberosity of calcaneus (both processes) • Some fibres from plantar aponeurosis (deep aspect)
Insertion	• Muscle ends in four tendons (for 2nd to 5th digits) • Each tendon divides into two slips (Fig 28.20) • The slips reunite and again separate to be inserted into the sides of the shaft of the middle phalanx	Medial side of base of proximal phalanx of great toe	Lateral side of proximal phalanx of fifth toe
Nerve supply	Medial plantar nerve (S2, 3)	Medial plantar nerve (S2, 3)	Lateral plantar nerve (S2, 3)
Action	• Flexion of middle and proximal phalanges • Steadies toes during walking • Helps to maintain arches of the foot	• Abduction of great toe • Flexion of great toe • Stabilises toes during walking • Helps to maintain arches of foot	• Abducts fifth toe • Stabilises toes during walk ng • Helps to maintain arches of foot
Note	The two slips of the tendon for each digit form a tunnel through which the tendon of the flexor digitorum longus passes to reach its insertion into the distal phalanx		

Table 28.4: Flexor digitorum accessorius (Fig. 28.22)

O igin	By two heads: Medial head from medial surface of calcaneus Lateral head from tuberosity of calcaneus (lateral process)
Insertion	Lateral border of tendon of flexor digitorum longus
Nerve supply	Lateral plantar nerve (S2, 3)
Actions	• Straightens oblique pull of flexor digitorum longus • It can flex the toes (through the tendon of the flexor digitorum longus)

Table 28.5: Lumbricals of foot

Origin (Fig 28.22)	These are four small muscles that take origin from the tendons of the flexor digitorum longus: • 1st lumbrical from medial side of tendon for 2nd toe 2nd lumbrical from contiguous sides of tendons for 2nd and 3rd toes • 3rd lumbrical from contiguous sides of tendons for 3rd and 4th toes • 4th lumbrical from contiguous sides of tendons for 4th and 5th toes
Insertion	Each muscle ends in a tendon that passes backwards on the medial side of one metatarsophalangeal joint and is inserted into the medial basal angle of the extensor expansion for that digit in the following order: • Tendon of first lumbrical into second digit • Tendon of second lumbrical into third digit • Tendon of third lumbrical into fourth digit • Tendon of fourth lumbrical into fifth digit
Nerve supply	• First lumbrical by medial plantar nerve (S2, 3) • Other umbricals by lateral plantar nerve (S2, 3)
Action	They maintain extension of interphalangeal joints of toes

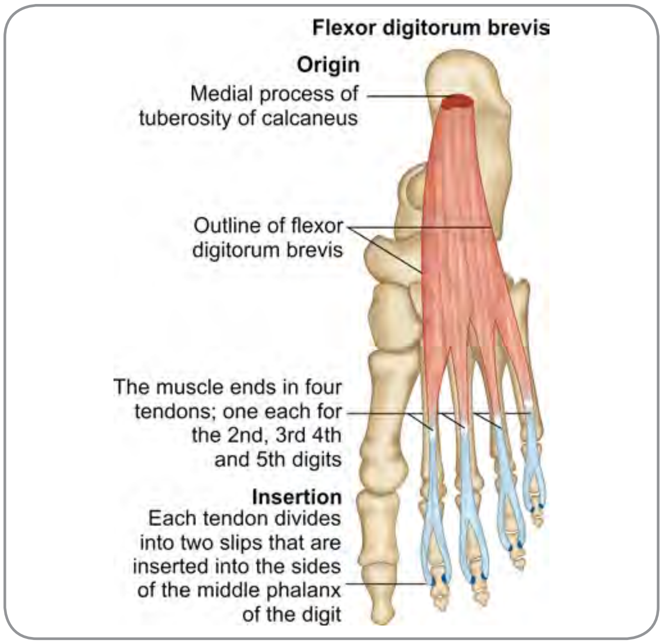


Fig. 28.19: Attachments of the flexor digitorum brevis

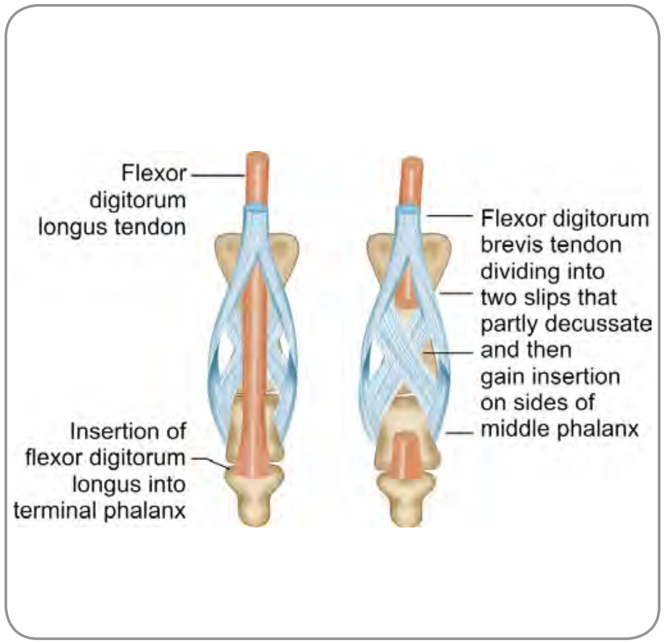


Fig. 28.20: Arrangement of tendons of flexor digitorum longus aand brevis over a digit

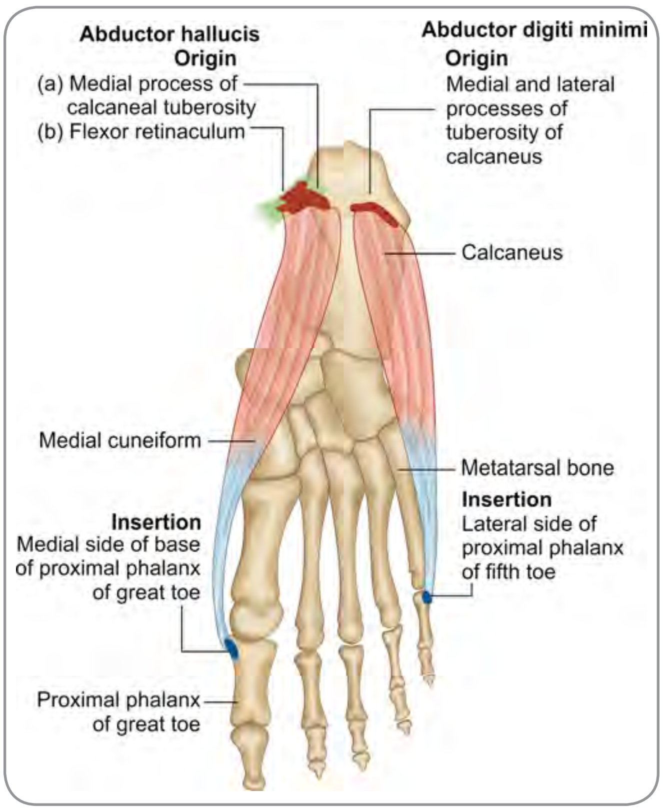


Fig. 28.21: Attachments of the abductor hallucis and the abductor digiti minimi

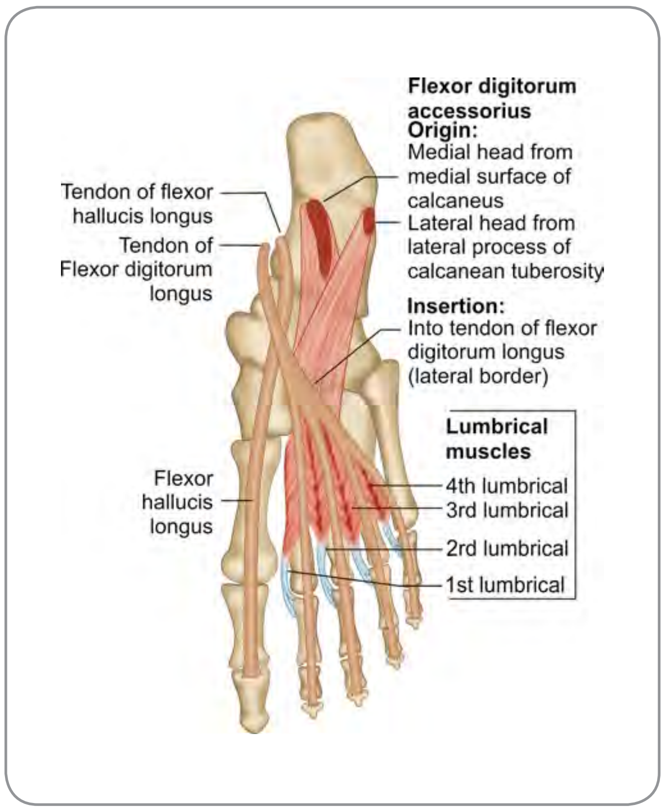


Fig. 28.22: Attachments of the flexor digitorum accessorius and the lumbrical muscles

Table 28.6: Muscles of the third layer of the sole

	Flexor Hallucis Brevis (Fig. 28 23)	Flexor Digiti Minimi Brevis (Fig. 28.23)	Adductor Hallucis (Fig. 28.24)
Origin	• Cuboid bone, plantar surface. • Lateral cuneiform bone (some fibres) • Some fibres from slips of tendon of tibialis posterior	• Base of fifth metatarsal bone (plantar surface) • Some fibres from sheath covering the tendon of peroneus longus	**Oblique head:** • Bases of 2nd, 3rd, 4th metatarsal bones • Sheath covering tendon of peroneus longus **Transverse head:** Ligaments on plantar aspect of metatarsophalangeal joints of 3rd, 4th and 5th toes
Insertion	Muscle divides into two parts. Each part is inserted into corresponding side of base of proximal phalanx of great toe	Proximal phalanx of little toe (on lateral side of base)	The two heads end in a common tendon. It is attached to the proximal phalanx of the great toe (lateral side of base).
Nerve supply	Medial plantar nerve (S2, 3)	Lateral plantar nerve (S1, 2)	Lateral plantar nerve (S2, 3)
Action	• Flexion of great toe • Stabilises the toe (by preventing extension during walking) • Helps in maintaining arches of foot	• Flexion of little toe • Stabilises the toe (by preventing extension during walking) • Helps in maintaining arches of foot	• Adduction of great toe • Stabilises the toe (by preventing extension during walking) • Helps in maintaining arches of foot

Table 28.7: Plantar and dorsal interosseous muscles of foot compared

	Plantar Interossei	Dorsal Interossei
Features common to both	• Numbered from medial to lateral side • Movements described with reference to the second digit • A plantar interosseous muscle is inserted into the base of the proximal phalanx of the digit concerned and into the dorsal digital expansion • Nerve supply from lateral plantar nerve (S2, 3). • They flex the metatarsophalangeal joint and extend the interphalangeal joints of the digit concerned	• Numbered from medial to lateral side • Movements described with reference to the second digit • A dorsal interosseous muscle is inserted into the base of the proximal phalanx of the digit concerned and into the dorsal digital expansion • Nerve supply from lateral plantar nerve (S2, 3) • They flex the metatarsophalangeal joint and extend the interphalangeal joints of the digit concerned
Features d fferent in the two	• Three plantar interossei • Each muscle arises from one metatarsal • The second digit does not give origin to, or receive the insertion of, any plantar interosseous muscle • These are ADDUCTORS of digits, tak ng them towards the line of the second toe • Plantar interossei take origin from and are inserted into, the third, fourth and fifth digits (not the second) • Insertion of each muscle into medial side of one digit, third, fourth and fifth	• Four dorsal interossei • Each muscle arises from two adjoining metatarsals • The second digit gives origin to, and receives insertions of, two muscles (one on each side: medial and lateral) • These are ABDUCTORS of digits taking them away from the line of the second toe • Dorsal interossei take origin from all five metatarsals and are inserted into the second, third and fourth digits (not first and fifth) • Insertion of first and second muscles into medial and lateral sides of second digit and of 3rd and 4th muscles into lateral side of corresponding digit

Additional Notes on the Interosseous Muscles of the Foot

Details of the attachments of individual interosseous muscles are easily remembered if their actions are first understood. ***The axis of the foot passes through the second digit***. Abduction and adduction movements of the toes are defined with reference to this line of axis.

The ***plantar interossei are adductors***. They pull the 3rd, 4th and 5th toes towards the second toe. The ***dorsal interossei are abductors***. With regard to the second digit, its movement to either medial or lateral side is abduction; specificity is given by naming the two movements as medial abduction and lateral abduction. The first dorsal interosseous muscle pulls the second toe medially. The second dorsal interosseous muscle pulls the same (2nd) digit laterally. The 3rd muscle pulls the 3rd digit, and the 4th muscle pulls the 4th digit laterally (i.e., away from the second digit).

In addition to abduction and adduction, the interossei flex the metatarsophalangeal joints and extend the interphalangeal joints by virtue of their insertion into the dorsal digital expansions

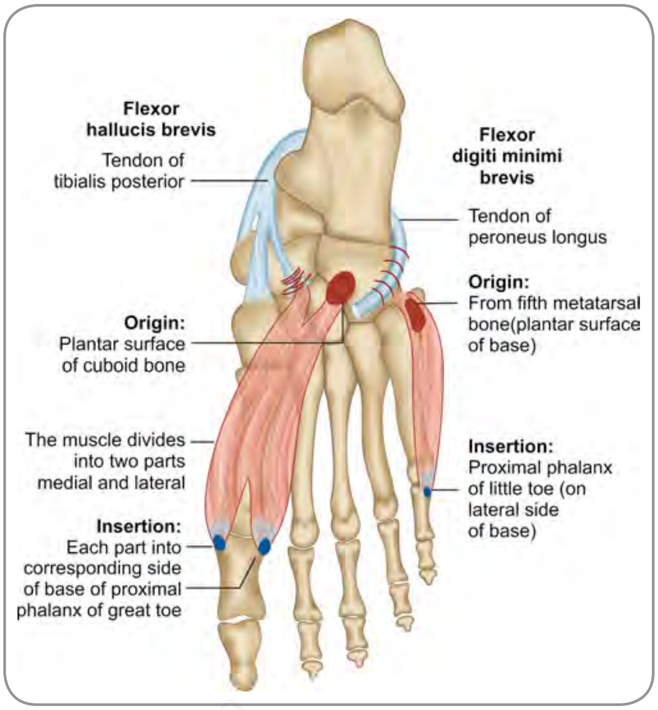


Fig. 28.23: Attachments of the flexor hallucis brevis and flexor digit minimi brevis

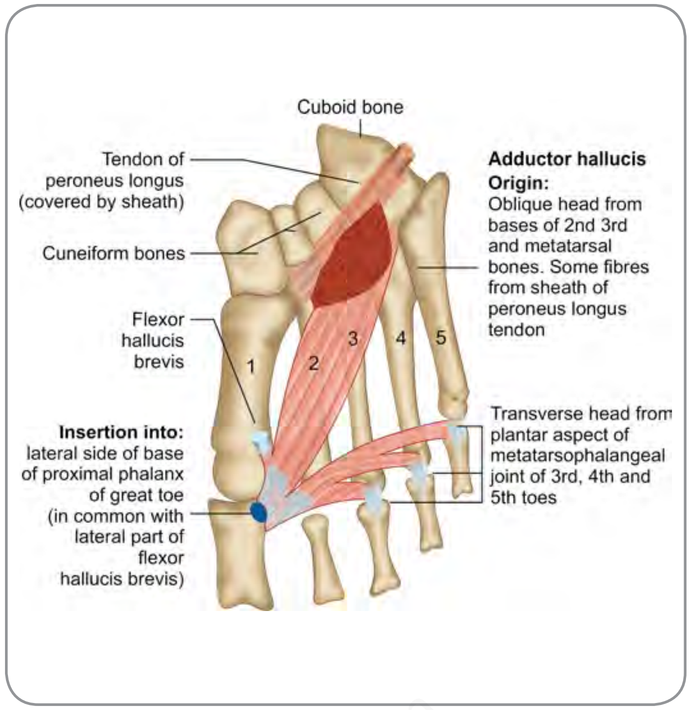


Fig. 28.24: Attachments of adductor hallucis

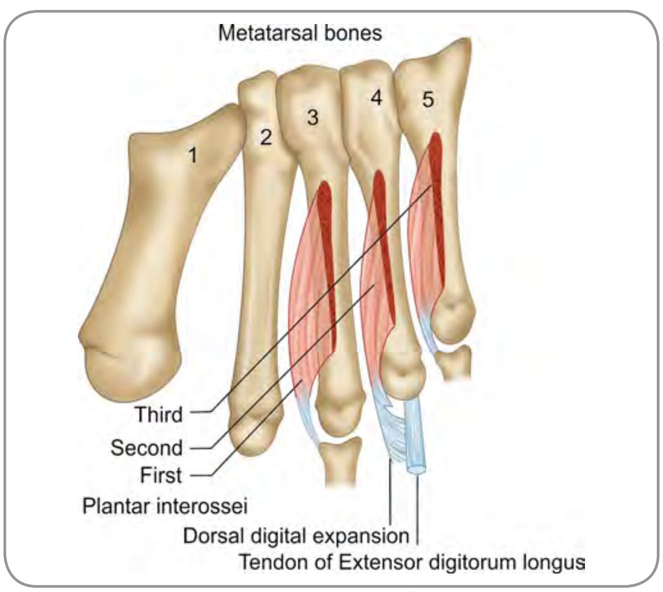


Fig. 28.25: Attachments of the plantar interossei of the foot

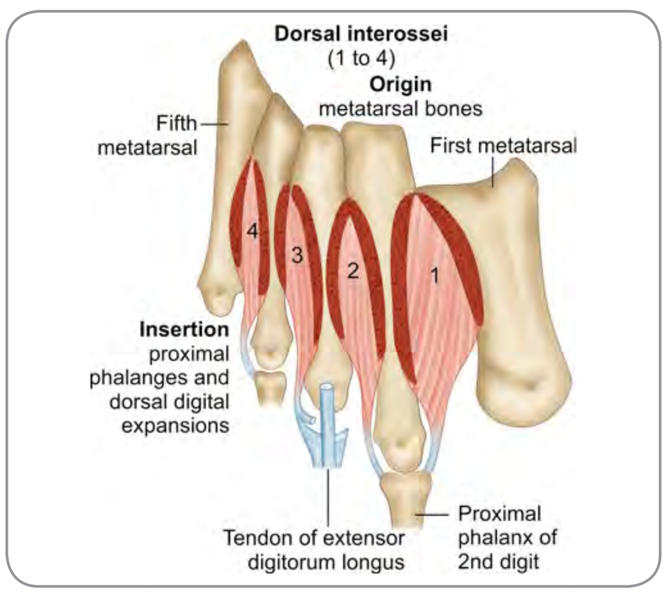


Fig. 28 26: Attachments of the dorsal interossei of the foot

Dissection

As the long flexor tendons are defined, identify the flexor accesorius muscle and the lumbricals. See the arrangement of the tendons and trace them to the point of entry into the fibrous tunnel. Trace the tendon to its insertion where the fibrous sheath is already opened up. Clean up one or two of the lumbricals till their tendons pass on the sides of the metatarsophalangeal joints.

Follow the long flexor tendons and the neurovascular bundle proximally to reach the flexor retinaculum. See how the various structures emerge from under cover of it. Preserve the flexor hallucis longus tendon. Cut the stem of the flexor digitorum longus tendon proximal to its division into slips and detach the flexor accessorius. Reflect the distal part of the tendon. The deeper layer of muscles come into view. Define and study them. Cut across the flexor hallucis brevis and, if necessary, the oblique head of adductor hallucis. Reflect them to expose the deep branch of lateral plantar nerve and the plantar arch. Trace the branches of the nerve and the artery. Trace the nervous and arterial branches entering the various muscles. Identify and study the exposed joints and try to locate the sesamoid bones, if any.

Cut the transverse head of adductor hallucis and reflect it. Locate the deep transverse metatarsal ligament. Cut the ligament on e ther side of the middle toe. Identify the interossei tendons. Trace the interossei muscles and study them.

Hold the tibialis posterior tendon near the flexor retinaculum. Trace it to its insertion. Study the various ligaments and joint capsules seen.

ARTERIES OF SOLE

The branches of medial and lateral plantar arteries and the plantar arch supply the structures of the sole.

Medial Plantar Artery

Course and Relations

The medial plantar artery, smaller of the two terminal branches of the posterior tibial, begins behind the medial malleolus, deep to the flexor retinaculum, and runs distally along the medial border of the sole of the foot. The medial plantar nerve lies lateral to the artery. At first, the artery is deep to the abductor hallucis muscle. Thereafter, it lies in the interval between the abductor hallucis medially and the flexor digitorum brevis laterally. The terminal end anastomoses with the branch of the first plantar metatarsal artery to the medial border of big toe.

Branches

The branches of the medial plantar artery are:

- ***Muscular branches***: To the muscles of the region.
- ***Cutaneous branches***: To the skin of the medial side of the sole.
- ***Digital branches***: Three small branches which join the first, second and third plantar metatarsal arteries.

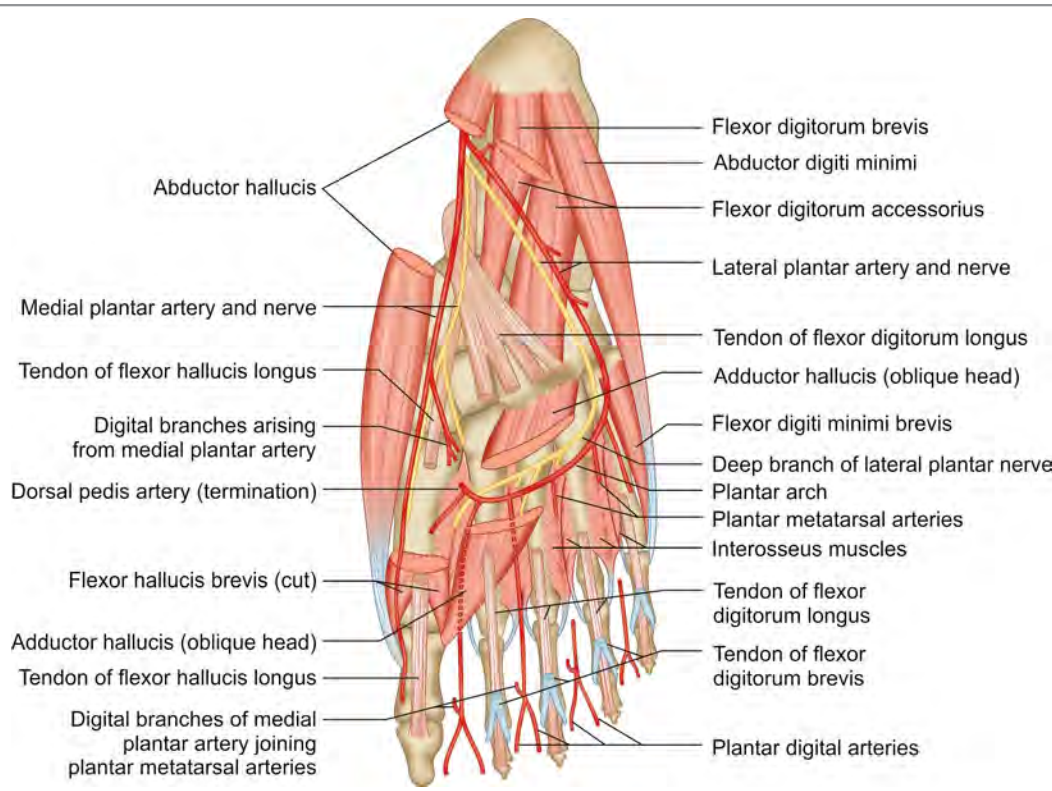


Fig. 28.27: Dissection to show the course and some branches of the main arteries and nerves of the sole

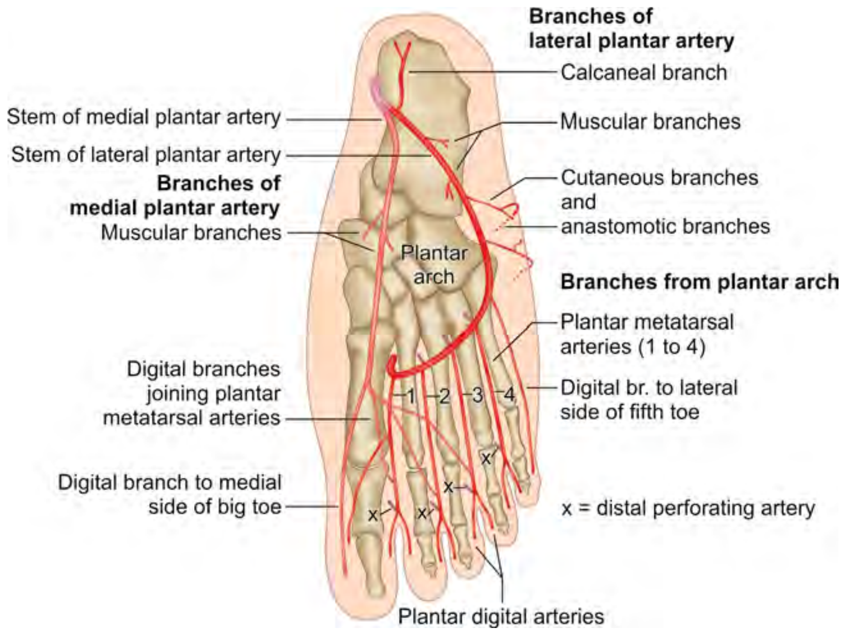


Fig. 28.28: Branches of medial and lateral plantar arteries

> **Surface Anatomy**
> A line is drawn from the point of bifurcation of posterior tibial arte y (the point midway between the medial malleolus and the prominence of heel) to the first interdigital cleft. Proximal half of this line indicates the medial plantar artery. Just distal to the midpoint of this line, the artery breaks into its digital branches.

Lateral Plantar Artery

Course and Relations

The lateral plantar artery is the larger of the two terminal branches of the posterior tibial artery. It begins behind the medial malleolus deep to the flexor retinaculum. At first it is deep to the abductor hallucis muscle. From there, it runs obliquely across the sole, laterally and distally to reach the base of the fifth metatarsal bone. This part of the artery is deep to the flexor digitorum brevis and lies over the flexor accessorius (in the first neurovascular plane). It then turns medially and runs deep in the sole across the bases of the metatarsal bones (in the second neurovascular plane). This part of the artery is called the ***plantar arch***. It ends by joining the termination of the dorsalis pedis artery (in the interval between the bases of the first and second metatarsal bones) The plantar arch is overlapped (apart from skin, fascia and plantar aponeurosis) by the flexor digitorum brevis, the tendons of the flexor digitorum longus and by the oblique head of the adductor hallucis muscle. The arch has a convexity proximally and a concavity distally. The deep branch of the lateral plantar nerve lies in the concavity.

Branches

The branches of the lateral plantar artery can be conveniently classified into those from the first part and those from the plantar arch (second part of the artery) Branches from the first part are:

- ***A calcaneal branch:*** It arises near the beginning of the artery and supplies the skin of the heel.
- ***Several muscular branches:*** To the muscles of the region.
- ***Several cutaneous branches:*** To supply the skin of the lateral part of the sole.
- ***A nastomotic branches:*** Which reach the lateral border of the foot and anastomose with arteries of the dorsum of the foot.

The branches arising from the plantar arch are:

- ***Proximal perforating arteries:*** Three in number which pass through the second, third and fourth intermetatarsal spaces and communicate with the dorsal metatarsal arteries (branches of arcuate artery).
- ***Plantar metatarsal arteries:*** Four in number, which run distally, one in each intermetatarsal space; each ends by dividing into two plantar digital branches for adjacent sides of two digits; the first artery also gives off a branch to the medial side of the great toe; the lateral side of the little toe gets a direct branch from the lateral plantar artery.
- ***Distal perforating arteries*:** Distal part of each plantar digital artery gives out a distal perforating artery that joins the distal part of the corresponding dorsal metatarsal artery.

Surface Anatomy

A line is drawn from the point of bifurcation of the posterior tibial towards the fourth toe. At the level of the fifth metatarsal, this line is continued across the sole with a convexity forward to the proximal end of the first intermetatarsal space. The first part of this line (till the fifth metatarsal) indicates the lateral plantar artery and the second part the plantar arch.

NERVES OF SOLE

The branches of the medial and lateral plantar nerves supply the structures of the sole.

Medial Plantar Nerve

Course and Relations

The medial plantar nerve is the larger of the two terminal branches of the tibial nerve. It begins on the posteromedial aspect of the ankle midway between the tendocalcaneus and the medial malleolus where it lies under cover of the flexor retinaculum. The nerve passes forward for a short distance in the medial part of the sole, at first deep to the abductor hallucis and then in the interval between this muscle and the flexor digitorum brevis. It is accompanied by the medial plantar artery that is medial to it. The nerve ends by dividing into one ***proper digital branch*** for the great toe, and three ***common plantar digital branches***.

Cutaneous Branches

- Branches arising from the trunk of the nerve supply the skin of the medial part of the sole.
- The skin on the medial side of the great toe is supplied by the proper digital branch to this digit.
- Each common plantar digital nerve divides into two ***proper digital nerves***.
  - The first (most medial) common plantar digital nerve divides into the proper digital nerves that supply the skin on the adjacent sides of the great toe and second toe.
  - The second nerve divides into branches that supply the second and third toes.
  - The third nerve divides into branches that supply the third and fourth toes.
  - Each digital nerve gives a dorsal branch that supplies the nail bed.

Muscular Branches

- Branches arising from the trunk of the nerve supply the abductor hallucis, and the flexor digitorum brevis.
- The flexor hallucis brevis receives a branch from the digital nerve to the great toe.
- The first lumbrical muscle is supplied by a branch from the first plantar digital nerve.

Articular Branches

Branches arising from the main trunk help to supply the tarsal and tarsometatarsal joints, while branches arising from the digital nerves supply metatarsophalangeal and interphalangeal joints.

Surface Anatomy

The medial plantar nerve is marked on the surface the same way as the medial plantar artery. The nerve lies lateral to the artery.

Clinical Correlation

- The medial plantar nerve may be compressed or irritated as it passes under the flexor retinaculum. There is pain on the medial side of the foot and in the heel. Sensations are abnormal. The condition is seen in long distance runners and hence called Runner's or ***Jogger's foot***.
- Neuromas may develop in any of the digital branches. The digital branch in the third interdigital cleft is the commonest to be so affected. Clinically referred to as the Morton's neuroma, it is a very painful condition.

Lateral Plantar Nerve

Course and Relations

The lateral plantar nerve is the smaller of the two terminal branches of the tibial nerve. It begins on the posteromedial aspect of the ankle midway between the tendocalcaneus and the medial malleolus. It passes forward and laterally across the sole, between the flexor digitorumbrevis (superficial to it) and the flexor accessorius (deep to it). At its termination, the trunk of the nerve lies in the interval between the flexor digitorum brevis and the abductor digiti minimi. The nerve ends (near the tubercle of the fifth metatarsal bone) by dividing into superficial and deep terminal branches. The trunk of the lateral plantar nerve is accompanied by the lateral plantar artery, which lies lateral to it (Note that the two nerves lie between the two arteries – the medial and lateral plantar nerves lie between the medial and lateral plantar arteries).

The ***superficial terminal branch*** runs distally and ends by dividing into two plantar digital nerves. The lateral of these runs along the lateral side of the fifth digit. The medial one divides into two branches that supply the adjacent sides of the fourth and fifth digits. The ***deep terminal branch*** begins near the tubercle of the fifth metatarsal bone. From here it runs medially towards the big toe, deep to the flexor tendons and the adductor hallucis.

Muscular Branches

- Branches arising from the trunk supply the flexor digitorum accessorius and the abductor digiti minimi.

- The flexor digiti minimi brevis is supplied by the digital branch for the lateral side of the fifth toe. This nerve also supplies the interosseous muscles that lie between the fourth and fifth metatarsal bones (i.e., the third plantar and the fourth dorsal interosseous muscles).
- The deep branch supplies all interossei except those lying between the fourth and fifth metatarsals. It also supplies the 2nd, 3rd and 4th lumbrical muscles, and the adductor hallucis (compare the distribution of the deep branch with that of the deep branch of the ulnar nerve).

Cutaneous Branches

- Some branches arising from the trunk of the nerve supply the skin of the lateral part of the sole.
- The skin on the lateral side of the little toe and the contiguous sides of the fourth and fifth toes is supplied by the corresponding digital branches.

Surface Anatomy

The lateral plantar nerve is marked on the surface the same way as the lateral plantar artery. The nerve lies medial to the artery.

Clinical Correlation

- ***The Plantar Reflex***: Stroking the lateral side of the sole of the foot (and carrying the stroke towards the base of the great toe) results in reflex flexion of the toes This is the normal response. In upper motor neuron paralysis (e.g., hemiplegia) there is an ***extensor response***. There is dorsiflexion (extension) of the great toe and fanning out of other toes. This is called the ***Babinski sign***. In children up to the age of four years an extensor response is normal. This is because the pyramidal tracts are not fully myelinated.
- ***Deformities of the Foot***: Congenital deformities are frequently seen in the region of the ankle and foot, and are of various types. The general term ***talipes*** is applied to them. In the most common type of deformity, the foot shows marked plantar flexion (= ***equinus***: like the foot of a horse), and inversion (= ***varus:*** inward bend). Hence this condition is called ***talipes equinovarus***. The medial longitudinal arch is high. In layman's language it is called ***club foot***. The condition may be unilateral or bilateral.
- Other types of talipes include (a) Talipes equinus, where the foot is plantar flexed and walking is on toes, (b) Talipes calcaneus, where the foot dorsiflexed and walking is on the heel, (c) Talipes varus, where the medial border is raised and walking is on the lateral border and (d) Talipes valgus, where the lateral border is raised and walking is on the medial border.
- The medial longitudinal arch of the foot may be poorly developed (***pes planus or flat foot***). A flat footed person may have difficulty in walking long distances, or in running. Conversely, the foot may be too highly arched (pes cavus). This condition is often associated with neurological disorders (including poliomyelitis).
- ***Deformities in the region of the toes*** can be produced by ill-fitting shoes. In ***hallux valgus***, there is lateral deviation of the big toe that may come to lie below, or above, the second toe. In ***hallux rigidus***, there is pain and limitation of movement of the big toe at the metacarpophalangeal joint. The deformity called ***hammer toe*** is usually seen in the 2nd, 3rd or 4th digits. The affected toe is hyperextended at the metacarpophalangeal joint, flexed at the proximal interphalangeal joint, and again hyperextended at the distal interphalangeal joint. Hammer toe can also be produced by paralysis of dorsiflexors of the foot.
- ***Metatarsalgia*** is a condition in which there is pain in the forefoot on walking. The pain is usually located in the interspace between the 3rd and 4th toes and is caused by pressure on the digital nerve present here.
- ***Ingrowing Toe Nail***: In this condition, seen in the big toe, one end of the distal edge of the nail grows into soft tissue causing pain and setting up inflammation. The condition can be prevented by trimming the nail straight and making sure that it does not grow into soft tissue In serious cases part of the nail may need removal.
- ***Paronychia***: This is infection of soft tissue in relation to a nail bed similar to that seen in the hand.
- ***Deep Plantar Abscess***: The space deep to the plantar aponeurosis may be infected. Infection can be drained by an incision parallel to the medial border of the foot.

Multiple Choice Questions

1. The superficial transverse septum of the posterior compartment:
   a. Is deep to soleus
   b. Is attached to the intercondylar fossa
   c. Separates the posterior tibial artery from flexor hallucis longus
   d. Separates popliteus from tibialis posterior.

2. Under cover of flexor retinaculum, the tendon of flexor digitorum longus is:
   a. Superior and medial to the tendon of flexor hallucis longus
   b. Inferior and medial to the tendon of tibialis posterior
   c. Inferior and lateral to the tendon of flexor hallucis longus
   d. Superior and lateral to the tendon of tibialis posterior.

3. When the knee is flexed, plantar flexion is caused by:
   a. Soleus alone
   b Gastrocnemius alone
   c. Soleus and medial head of gastrocnemius
   d. Soleus and both heads of gastrocnemius.

4. Flexor hallucis longus coordinates maintenance of medial longitudinal arch:
   a. By its attachment to big toe
   b. Through the Turner's slip
   c. By passing below the sustentaculum tali
   d. Because it lies on the medial side of calcaneus.

5. Plantar interossei:
   a. Arise from adjoining metetarsals
   b. Adduct the toes
   c. Insert to the lateral sides of digits
   d Also extend metatarsophalangeal joints.

ANSWERS

1. a **2.** a **3.** a **4.** b **5.** b

Clinical Problem-solving

Case Study 1: A 34-year-old man complained of pins and needles in his right sole. He also had burning sensation on and off. His physician advised certain investigations. However, he also examined the medial aspect of the man's right foot and asked the man to invert his foot. As the man told that 'that' area was alright, the physician said he was looking out for any swelling or tenderness in that area.

- Can you suggest what the physician was looking for? And why particularly in the medial aspect of foot?
- Which nerve was involved in this case?
- Can you name a similar condition in the upper limb and what structure gets involved then?

Case Study 2: A medical student was trying to practically check whatever he learned in his class. He tried to test the plantar reflex in all the members of his family.

- What type of 'normal' response should he expect in his father?
- Will the response be the same in his father and his 2½-year-old niece?
- Why is the response different? What is it called?

(For solutions see Appendix).

Chapter **29**

Joints of Lower Limb

Frequently Asked Questions

- Write notes on: (a) Pubic symphysis, (b) Sacrotuberous ligament, (c) Acetabulum, (d) Avascular necrosis of head of femur, (e) Bryant's triangle, (f) Coxa vara and valga, (g) Trendelenberg's sign, (h) Deltoid ligament, (i) Menisci of knee joint
- Discuss the hip joint with regard to its articular surfaces, igaments, relations, nerve and blood supply, and movements.
- Discuss the knee joint with regard to its articular surfaces, ligaments, relations, nerve and blood supply, and movements.
- Discuss the ankle joint with regard to its articular surfaces, ligaments, relations, nerve and blood supply, and movements.
- Write notes on: (a) Ligaments of knee joint, (b) Cruciate ligaments, (c) Bursae around knee, (d) Brodie's bursa, (e) Intracapsular extrasynovial structures of knee, (f) Movements of knee, (g) Locking and unlocking of knee, (h) Inversion-eversion movements, (i) Spring ligament, (j) Bifurcate ligament, (k) Long plantar ligament, (l) Short plantar ligament
- Write about the subtalar joint and discuss the movements occurring in this joint.
- Discuss the talocalcaneonavicular joint and its movements.
- Write detailed notes on: (a) Medial longitudinal arch, (b) Lateral longitudinal arch, (c) Transverse arch of foot, (d) Flat foot, (e) Hallux valgus, (f) Talipes of foot.

Joints of the lower limb include the joints of the pelvis. The human body has acquired an erect posture during the process of evolution. The joints of the lower limb, therefore, will have to withstand much load on account of weight-bearing and locomotion. Anatomical features add to the efficacy of the joints.

The most important function of the joints of the lower limb is weight bearing. Body weight is transferred from the vertebral column through the sacroiliac joints to the pelvis and from the pelvis through the hip joints to the femora (singular, femur, plural, femora). The femora, as can be easily noticed, are obliquely placed with an infero-medial tilt. This causes the two knee joints to come adjacent and closer to one another, thus placing them directly below the trunk. The obliquity of the femora and the closeness of the knee joints, bring the centre of gravity to a stable position, helping in proper weight transmission and balance of the body.

JOINTS AND LIGAMENTS OF PELVIS

The joints of the pelvis are the sacroiliac joints and the pubic symphysis. The sacroiliac joints connect the axial skeleton (the vertebral column, sacrum being part of it) to the inferior appendicular skeleton (skeleton of lower limb). Though the lumbosacral and sacrococcygeal joints are part of the axial skeleton, they are sometimes grouped with the joints of the pelvis because of their direct relation.

PUBIC SYMPHYSIS JOINT

This joint unites the bodies of the two pubic bones in front. In structure, it corresponds to that of a secondary cartilaginous joint. A ***fibrocartilaginous interpubic disc*** connects the two pubic surfaces which are covered by hyaline cartilage. The joint, which does not have a joint cavity, is further strengthened by the surrounding ligaments. The ***superior pubic ligament*** runs on the superior aspects of the pubic bodies and the interpubic disc. The ***inferior pubic ligament*** (otherwise called the ***arcuate ligament***) connects the inferior pubic rami of both sides. The pubic arch and the subpubic angle formed in the angulation between the two inferior pubic rami are thus rounded off. An ***anterior pubic ligament*** running between the anterior surfaces of both sides is also present. Tendinous attachments of the rectus abdominis

and external oblique muscles also add to the strength of the joint. Pubic branches of obturator, superficial external pudendal and inferior epigastric arteries supply the joint and innervation is by twigs from iliohypogastric, ilioinguinal and pudendal nerves. Though the joint has only limited mobility, the rotational movements of this joint that accompany movements of hip and trunk help in absorbing shocks. Considerable movement along with some separation of the pubic symphysis occurs during child birth.

SACROILIAC JOINTS

These are strong, weight bearing joints The sacrum articulates on each side with the corresponding ilium forming the right and left sacroiliac joints. These are synovial.

The iliac and sacral surfaces are both shaped like the auricle (pinna) and are, therefore, called ***auricular surfaces***. The surfaces are covered by cartilage; this cartilage on both the ilial and sacral sides, is more of fibrocartilage with interspersed areas of hyaline cartilage. Because of the presence of a number of raised and depressed areas the joint allows little movement. This feature of limited mobility makes the sacroiliac joint very different from most other synovial joints and is consequent to its role in weight transmission. The shape and irregularity of the auricular surfaces vary considerably in different individuals and also between the sides of the same individual.

The joint is synovial with a fibrous capsule and a lining synovial membrane. However, the joint capsule is greatly reduced due to the close proximity of the two articular facets. The raised and depressed areas of the articular facets cause interlocking between themselves and this further reduces the joint cavity. In later life, fibrous and fibrocartilaginous adhesions between the articular surfaces are seen with partial or complete obliteration of the joint cavity. This has prompted some authors to describe the joint to have an anterior synovial component and a posterior syndesmosis component.

The capsule of the joint is attached around the margins of the articular surfaces. It is thickened in its anterior part to form the ***ventral (or anterior) sacroiliac ligament***.

It runs from the anterior margin of the sacral auricular surface to the pre-auricular sulcus of ilium. The main bond of union between the sacrum and ilium is, however, the ***interosseous sacroiliac ligament*** that is attached to the rough areas above and behind the auricular surfaces of the two bones. A deep band and a superficial band can be made out. The deep band runs between the depression behind the sacral auricular surface and the depression on the iliac tuberosity. On the sacrum, the superficial band (frequently called the ***short posterior ligament***) is attached to the lateral crest of its first two pieces while on the ilium, it is attached to the area behind the depression. The interosseous sacroiliac ligament is the primary structure involved in transmitting weight of the body from the vertebral column to the ilium. The intermediate and lateral crests of the sacrum are connected to the posterior-superior iliac spine and the adjacent iliac crest by a strong ***dorsal (or posterior) sacroiliac ligament*** which covers the interosseous ligament from behind. In the abundant mass of fibrous tissue found on the posterior aspect of this area, yet another ligament can be differentiated. This is the ***long posterior sacroiliac ligament*** that runs between the third and fourth pieces of sacrum to the posterior superior iliac spine.

Other ligaments of the region assist the sacroiliac joint in weight transmission and in maintaining its stability. These are the iliolumbar ligament, the sacrotuberous ligament and the sacrospinous ligament.

The sacroiliac joint is the most stable joint of the body. The stability of the joint and its extreme capacity to support the body weight depend on several factors. These are:

- Reciprocal irregularity of the articular surfaces—which leads to restriction in mobility.
- The fibres of interosseous, posterior and long posterior sacroiliac ligaments running upwards and outwards from the sacrum—when sacrum tends to be pushed down by body weight, these fibres actually pull the ilia medially, thereby compressing the sacrum between them and locking the joint.
- Aid of accessory ligaments—displacement of L5 vertebra over sacrum due to impact of body weight is resisted by the iliolumbar ligament and upwards tilt of lower sacrum due to impact of body weight on upper sacrum is resisted by the sacrotuberous and sacrospinous ligaments.
- Position and shape of sacrum—the articular surfaces of sacrum are farther apart in front than behind, so the sacrum behaves as the reverse of a keystone, tending to sink forwards into the pelvis – this causes the ligaments to act and pull the ilia closer.

All these factors act as components of an ***automatic locking device*** and aim at tight apposition between the articular surfaces.

The joint is supplied by branches of iliolumbar, lateral sacral and superior gluteal arteries. Twigs from superior gluteal nerve, from anterior rami of S1, S2 and from posterior primary rami of S1, S2 innervate.

Slight gliding and rotary movements occur in the joint. Antero-posterior movements are useful during flexion and extension of the trunk

OTHER LIGAMENTS OF PELVIS

Iliolumbar Ligament

It connects the tip of transverse process of the fifth lumbar vertebra to the iliac crest in front of the sacroiliac joint. In addition to offering resistance to displacement of L5 over sacrum, it also aids in pulling the ilium medially.

Sacrotuberous Ligament

This large and strong ligament is triangular and has a broad upper medial end (base) and a narrower lower lateral end (apex). The base is attached (from above to downwards) to:
- The posterior-superior and posterior-inferior iliac spines.
- The lower part of the posterior surface of the sacrum (transverse tubercles).
- The lateral margin of the lower part of the sacrum and the upper part of the coccyx.

The apex is attached to:
- The medial margin of the ischial tuberosity.
- The lower margin of the ramus of ischium.

The apex is not strictly convergent. As the fibres reach the ischial tuberosity, they twist upon themselves and become divergent to be attached to the medial margin of the tuberosity and the lower margin of the ischial ramus. The fibres which are continued onto the ischial ramus form a sickle-shaped extension called the ***falciform process*** (Fig. 29.1).

This ligament converts the sciatic notch of the hip bone into a sciatic foramen which is further subdivided into the greater and lesser sciatic foramina by the sacrospinous ligament. On its outer (gluteal) surface, it gives origin to fibres of gluteus maximus and the long head of biceps femoris. The ligament is pierced by the coccygeal branch of inferior gluteal artery and the perforating branch of coccygeal plexus.

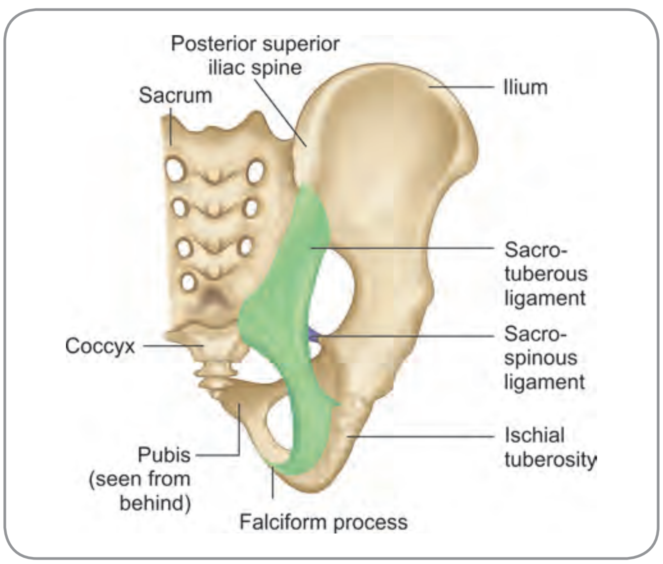


Fig. 29 1: Posterior aspect of the pelvis showing the attachments of the sacrotuberous and sacropinous ligaments

Sacrospinous Ligament

This is also a triangular ligament with a medially placed at base attached to the sacrum and coccyx and a laterally placed apex attached to the ischial spine. It is anterior to the sacrotuberous ligament and morphologically, represents parts of the coccygeus muscle. The coccygeus muscle (persisting as muscle fibres) lies anterior to it (Fig. 29.1).

Added Information

A small slit like cavity appears in the superior part of the inter-pubic disc during early life; this extends later in women through most part of the fibrocartilaginous disc. This cavity has no synovial lining and should not be mistaken for a joint cavity. The cavity and the separation of pubes that it produces contribute to widening of pelvis.

Clinical Correlation

Pregnancy and after pregnancy: Due to hormonal influences, the interpubic disc enlarges in size during pregnancy and this contributes more to the separation of pubic symphysis and widening of pelvis. Increased levels of sex hormones and the presence of hormone relaxin cause the pelvic ligaments to relax during later part of the pregnancy, thus causing increased movements at the pelvic joints. Relaxation of sacroiliac ligaments compromises the locking system of the sacroiliac joint; as a consequence, rotation of pelvis occurs easily, leading to the lordotic posture (swaying back) often seen.

HIP JOINT

The hip joint (or the ***coxal joint***) can be described as the most important joint of the lower limb. On one hand, all types of movements, which are essentially required for effective locomotion of an individual, occur in this joint. On the other hand, the force of body weight which is transmitted through the vertebral column in the trunk, is directed to the lower limbs at the level of the hip joints. Thus the hip joint has important roles to play in both mobility and stability of an individual.

It is truly a connection between the pelvic girdle and the lower limb and is a multiaxial synovial joint of the ball and socket variety. It is formed between the hip bone proximally (the acetabulum of hip bone forming the socket) and the femur (the head of femur forming the ball) distally.

Dissection

Cut the femoral vessels and the femoral nerve immediately below the inguinal ligament. Cut the sartorius, rectus femoris and pectineus muscles closer to their origins and reflect them down. Identify iliopsoas and cut it above, its insertion reflects it upwards.

The capsule of the hip joint is now exposed. Study the ligaments of the joint. Identify psoas bursa. Open it into the joint cavity by cutting across the anterior part of the capsule with a sharp scalpel. The iliofemoral ligament will also be cut across.

Observe the articular cartilages. Try to rotate and abduct the femoral head; the ligamentum teres will be exposed. Study it.

Identify the obturator externus muscle which courses inferior to the femoral neck. Reflection of this muscle will expose the pubofemoral ligament. Study it.

Turn the cadaver to prone position. After clearing up the muscles in the posterior aspect of the hip joint, make an incision in the posterior capsule to enter the joint cavity.

After studying the internal structures, disarticulate the joint by cutting the ligamentum teres and remaining parts of the capsule. Study the articular surfaces and the attachments of the various ligaments.

Articular Surfaces (Fig. 29.2)

The ***acetabulum*** (Latin. vinegar cup) is a hollow cup on the lateral aspect of the hip bone and is deepened further by the ***acetabular labrum*** (Fig. 29.3). However, the cavity of the acetabulum is partly articular and partly non-articular. The articular part is shaped like a horse-shoe (Fig. 29.4) and is called the ***lunate surface***. It covers the anterior, superior and posterior walls of the acetabulum. The articular area is widest superiorly and is also the area where maximum body weight is transmitted to the femur. The cartilage lining the acetabulum is thickest at this area. The non-articular part occupies the curve of the lunate surface and thus is on the inferior aspect of the acetabulum; it is called the ***acetabular fossa*** and is covered with fat. The rim of the acetabulum is deficient at the non-articular area, thus giving rise to the ***acetabular notch***.

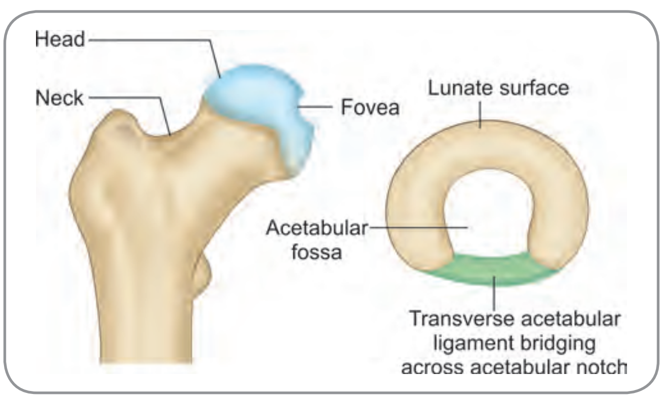


Fig 29.2: Articular surfaces of the hip joint

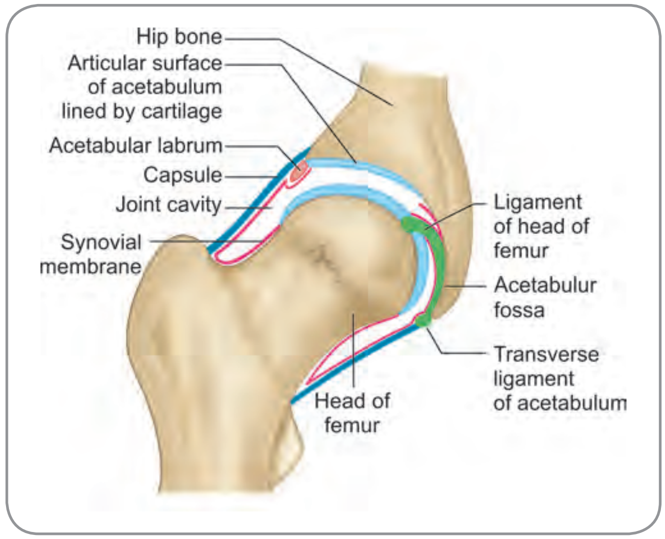


Fig. 29.3: Schematic section across the hip joint

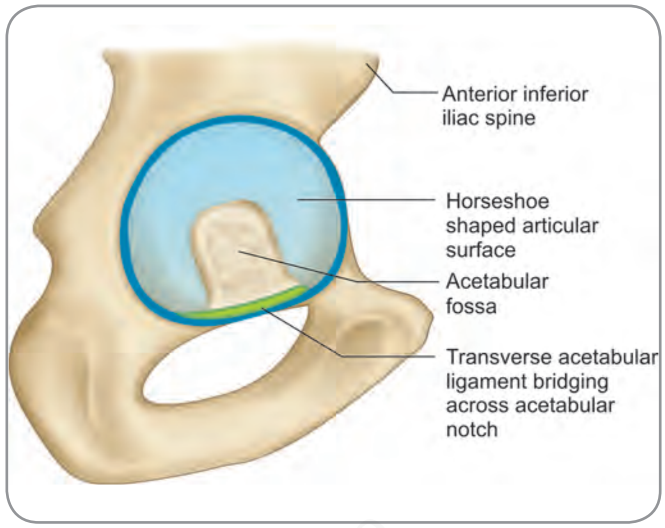


Fig. 29.4: Part of right hip bone (lateral aspect) to show the attachment of the capsule of the hip joint

The ***head of femur*** which is the distal articular surface of the hip joint, is more than half of a sphere and faces upwards, forwards and medially. Near its centre is a pit called the ***fovea*** (or ***fovea capitis***). Except for the fovea, the rest of the femoral head is covered with articular cartilage which is thickest in the centre (the weight bearing area) and thinnest at the periphery, having the effect of increasing the convexity of the head.

Articular Capsule

The capsule of the hip joint is very strong. Proximally (or medially), it is attached to the hip bone just above the margin of the acetabulum. The attachment is beyond the acetabular labrum, thus making the latter an intracapsular

structure. At the acetabular notch, the capsule is attached to the external aspect of the transverse acetabular ligament and the margin of the obturator foramen beyond the ligament. Distally (or laterally), it covers the greater part of the neck of the femur. Anteriorly, it is attached to the trochanteric (same as intertrochanteric) line; posteriorly, the capsule extends, on the neck of the femur, to a short distance medial to the trochanteric (same as intertrochanteric) crest; above to the base of the greater trochanter; and inferiorly to the neck near the lesser trochanter. On the posterior aspect the capsular fibres are not attached to the bone there. Instead they curve and wind spirally to reach the anterior aspect of the femur and get attached to the upper part of the trochanteric line. Hence, it is possible to separate the posterior aspect of the capsule from the bony aspect of the neck of femur.

The capsular fibres are denser and thicker anteriorly. They are in two sets, namely the inner circular set and the outer longitudinal set. The inner set of fibres occurs only at the middle of the capsule and passes circularly around the neck of femur. They form the ***zona orbicularis.*** These circular fibres cause an hour-glass constriction of the joint cavity and help in retaining the femoral head within the acetabulum. The outer set of fibres, though longitudinal, takes a spiral course from the hip bone to the femur. Many of these longitudinal fibres attached to the front of the neck of femur, turn sharply to run on it towards the head—they form longitudinal bundles called ***retinacula***. Blood vessels for the head and neck pass through these retinacula.

Ligaments

The ligaments of the hip joint are:

- Acetabular labrum.
- Transverse acetabular ligament.
- Ligament of the head of femur.
- Ilio femoral ligament.
- Ischiofemoral ligament and the.
- Pubofemoral ligament.

Acetabular Labrum

This is a fibrocartilaginous structure attached to the acetabular margin. It deepens the acetabular cavity. The labrum is triangular in cross-section; the base of the triangle is attached to the acetabular margin and the apex is free. This arrangement helps the labrum to grip the head of femur beyond its equator and thus provide stability to the joint.

Transverse Acetabular Ligament

It is a continuation of the acetabular labrum across the acetabular notch. The notch is thus converted into a foramen through which vessels and nerves of the joint pass. The transverse acetabular ligament has no cartilage cells and is a bundle of densely packed strong fibres.

Ligament of the Head of Femur

Also called the ***ligamentum teres***. This is a triangular structure, whose base is attached to the transverse acetabular ligament and to the sides of the acetabular notch. From the base, it tapers into a flat band. At the apex, the flat band gives way to a rounded structure that gets attached to the fovea on the head of femur. This ligament holds the head of femur in position. It lies within the joint cavity and so, is ensheathed by synovial membrane. A branch from the obturator artery usually runs in this ligament to supply the head of femur (though its supply is often inadequate). More twigs from the acetabular branches of the obturator and medial circumflex arteries may also be found.

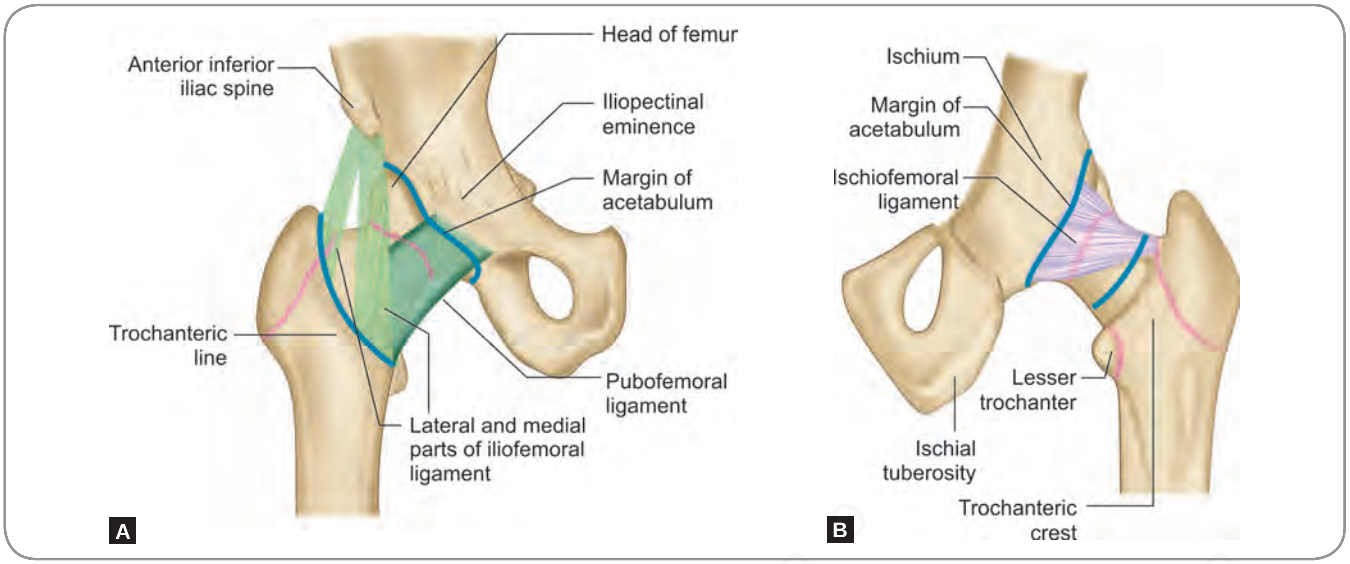
The other three ligaments of the hip joint are thickened parts of the fibrous capsule itself. The fibrous capsule, as already noticed, runs from the acetabulum to the femur. The acetabulum is made up of all three parts of the hip bone, namely—(1) the ***ilium***, (2) the ***ischium*** and (3) the ***pubis***. The three ligaments connect these three bones with the femur are—(1) ***Iliofemoral ligament***, (2) ***Ischiofemoral***, ***ligament***, (3) ***Pubofemoral ligament***.

Iliofemoral Ligament

As the name implies, this ligament runs between the ilium and the femur. It is on the anterior aspect of the joint and is triangular in shape. The apex is attached to the anterior inferior iliac spine (ilium) and to the base to the trochanteric line (femur). However, the margins are thicker and the central portion is weak. So the ligament appears like an inverted 'Y' and is often called the ***'Y' ligament of bigelow***. The two limbs of the Y run to the femur. The medial limb is vertical and attaches to the lower part of the trochanteric line. The lateral limb is inclined to the upper part of the same line. Since the lateral limb appears to run from the anterior inferior iliac spine to the base of the greater trochanter, it is sometimes called the iliotrochanteric ligament. The iliofemoral ligament is the strongest ligament of the body and resists over-extension of the joint. During standing, the centre of gravity of the body passes behind the head of femur. This causes the body to sway backwards. The swaying back is resisted by the iliofemoral ligament, thus helping in maintaining an erect posture. The ligament also checks lateral rotation of the thigh (Fig. 29.5A).

IschioFemoral Ligament

This ligament, which is otherwise called the ischiocapsular band and which runs between the ischium and the femur, is on the posterior aspect of the capsule. Proximally it is



Figs 29.5A and B: Hip joint **A.** Anterior aspect **B.** Posterior aspect; The capsular attachments (blue) and epiphyseal lines (magenta) are shown

attached to that part of the ischium just below the acetabulum and distally to the upper part of the trochanteric line deeper to the lateral limb of the iliofemoral ligament. Similar to the fibres of the posterior part of the capsule, the fibres of the ischiofemoral ligament also spiral around the neck of femur and reach the anterior attachment. It resists excessive medial rotation and extension of the thigh (Fig. 29.5B).

Pubofemoral Ligament

This is a triangular ligament, otherwise called the pubocapsular band. Its base is attached to the iliopectineal eminence, superior pubic ramus and to the obturator crest. The fibres converge at the apex which is attached to the lower part of the trochanteric line deeper to the medial limb of the iliofemoral ligament. It checks the extension and abduction of the thigh (Fig. 29.5A).

Synovial Membrane

The synovial membrane lines the joint cavity and is attached to the articular margins. From the articular margin on the head of femur, it covers that part of the neck which lies within the joint capsule. Then it gets reflected to the internal aspect of the capsule. From the acetabular aspect of the capsule, it runs over the external surface of the acetabular labrum and gets attached to the articular margin. From the transverse acetabular ligament, it ensheaths the ligament of the head of femur on one side and on the other, it covers the fat in the acetabular fossa.

A small pouch of the synovial membrane may protrude through the anterior wall of the capsule between the pubofemoral and the iliofemoral ligaments; this forms a bursa beneath the psoas tendon and is called the ***psoas bursa*** (or the subtendinous iliac bursa). On the posterior aspect, since the joint capsule is not attached to bone, a small portion of the synovial pouch may protrude onto the neck of femur beyond the capsule This forms a bursa for the tendon of obturator internus.

Relations

- ***Anterior:*** (from medial to lateral) pectineus, iliopsoas and rectus femoris; pectineus separates joint from the femoral vein; iliopsoas separate the joint from femoral artery and nerve.
- ***Inferior:*** Pectineus and the tendon of obturator externus behind it.
- ***Posterior:*** Tendon of obturator externus separates the lower part of the joint from quadratus femoris; above the quadratus femoris, are the inferior gamellus, the tendon of obturator internus, superior gamellus and piriformis (in that order from below upwards); sciatic nerve and inferior gluteal artery are separated from the joint by the same muscles.
- ***Superior:*** Reflected head of rectus femoris and the gluteus minimus lateral to it (Fig. 29.6).

Blood Supply

Arterial supply to the joint is derived from the medial and lateral circumflex femoral arteries (branches of profunda femoris) and the artery of head of femur (branch of obturator artery). The artery of the head runs through the ligament of the head and supplies the central part of the head. Major supply to the joint is from the retinacular arteries that arise from the medial and lateral circumflex femoral arteries. The retinacular arteries run beneath the retinacular fibres of the capsule and reach the internal structures of the joint. Retinacular branches from the

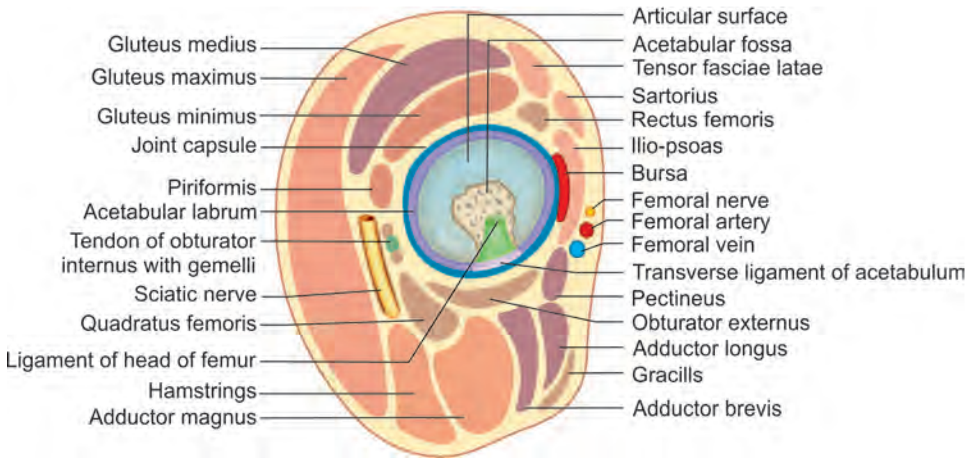


Fig. 29 6: Schematic diagram to show structures around the hip joint

medial circumflex femoral are more and larger; they easily pass underneath the retinacular fibres because the posterior part of the capsule is not attached to bone. Retinacular branches from the lateral circumflex femoral are fewer and smaller and have to pierce the dense iliofemoral ligament to reach under the retinacular fibres.

Nerve Supply

Branches of femoral, obturator, sciatic and superior gluteal nerves and the nerve to quadratus femoris supply the joint.

Movements

The hip joint has a wide range of movements—***Flexion—extension***, ***Abduction—adduction***, ***Medial rotation—lateral rotation*** and ***circumduction*** can occur. Movements of the trunk at the hip joints (when the lower limbs are fixed) are also important. The degree of flexion extension possible at the hip, depends on the position of the knee. When the knee is flexed and thereby the hamstrings relaxed, the hip can be flexed until the thigh touches the anterior abdominal wall. When the knee is extended, flexion at hip is limited by tension in hamstrings. Extension at the hip causes the joint capsule and the ligaments, especially the iliofemoral ligament, to become taut. So the hip can only be extended slightly beyond the vertical. Further extension (or hyperextension) will be possible only when the pelvis is moved and the lumbar vertebral column flexed. The range of abduction is more than that of adduction; more abduction and adduction are possible when the hip is flexed than it is extended. Lateral rotation is more powerful than medial rotation. In circumduction, the limb swings around a cone of the apex of which is in the hip joint (Table 29.1).

Table: 29.1: Movements of the hip joint (Fig. 29.7)

Movement	Muscles producing	Factors limiting
Flexion	Iliopsoas, rectus femoris, sartorius and to a smaller extent the adductors, pectineus and gracilis	Contact with abdominal wall, tension in hamstrings
Extension	Gluteus maximus (primary extensor); Hamstrings (additional extension from the straight position)	Tension in the joint capsule and the iliofemoral, ischiofemoral and pubofemoral ligaments
Abduction	Gluteus medius and gluteus minimus; assisted by sartorius, tensor fascia latae and piriformis	Tension in the pubofemoral ligament
Adduction	Adductor longus, adductor brevis and adductor part of adductor magnus; assisted by pectineus and gracilis	Contact with opposite limb and tension in the ligament of head of femur
Medial rotation	Anterior fibres of gluteus medius and gluteus minimus; tensor fascia latae	Tension in the ischiofemoral ligament
Lateral rotation	Piriformis, obturator internus and externus, superior and inferior gamelli, quadratus femoris; assisted by gluteus maximus.	Tension in iliofemoral and pubofemoral ligaments

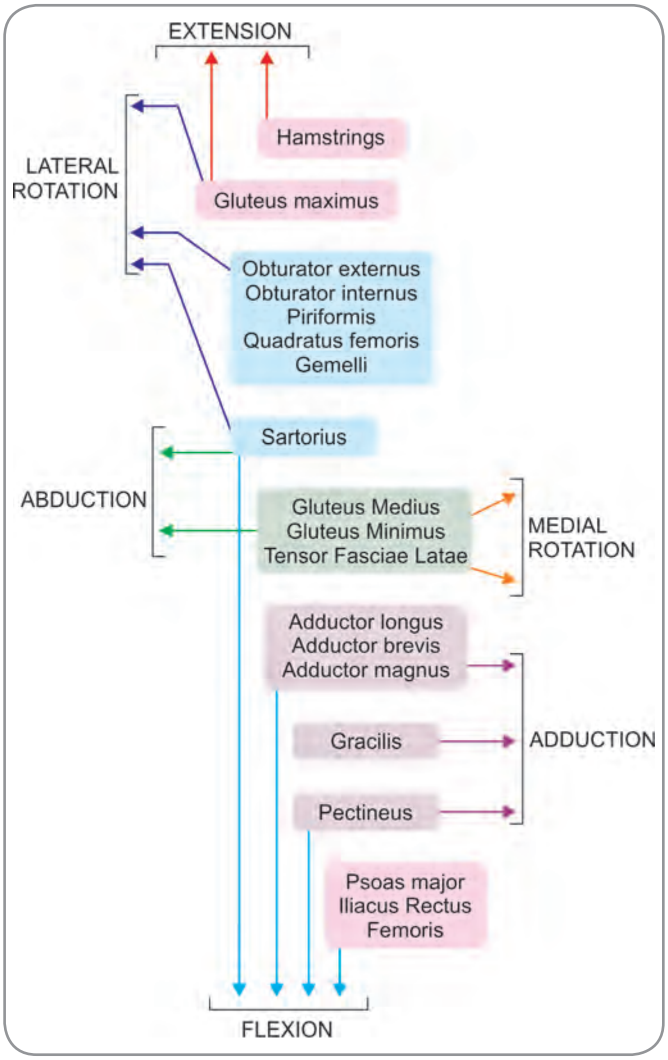


Fig. 29.7: Scheme to show muscles responsible for movements at the hip joint

Added Information

- Extensors and lateral rotators are more powerful than the flexors and medial rotators respectively.
- Iliopsoas is the strongest flexor of hip.
- Adductor magnus, in addition to being an adductor, also functions as a flexor (its anterior part) and an extensor (its posterior part).
- The iliofemoral, ischiofemoral and pubofemoral ligaments pass from the pelvis to femur in a spiral fashion. Extension causes more winding and spiralling of these ligaments, thus constricting the capsule and drawing the femoral head deeper into the acetabulum. This restricts the extension movement but adds to the stability of the joint. Flexion unwinds the ligaments and therefore, permits more flexion and more mobility.
- Medial rotation winds the ligaments and lateral rotation unwinds them.
- All the three axes around which movements occur in the hip joint, intersect at the centre of the head of femur.

contd...

Added Information *contd...*

- Due to the var ations in the attachments of the capsule on the anterior and posterior aspects of the neck region of the femur, the whole of the anterior neck is intracapsular but on the posterior, only part of it is inside the capsule
- The articular surfaces of the acetabulum and the femur are maximally congruent, when the hip is partially flexed, abducted and laterally rotated. However, the maximally close-packed position is extended with slight abduction and medial rotation, when the ligaments and the capsule are taut.
- On the anterior aspect of the hip joint, the muscles are less abundant and so the ligaments are very strong; on the posterior aspect, the muscles are abundant and the ligaments are weaker.
- Acetabulum acetabular labrum and the transvers acetabular ligament together are referred to as the acetabular complex.
- The hip joint is designed in such a way that the thicker and weight-bearing ilium is placed directly above the head of femur for efficient transfer of weight to the femur.
- The stability of the hip joint depends on—(a) the depth of acetabular cup and the narrowing of its mouth produced by the acetabular labrum, (b) the strong ligaments, (c) the strength of the surrounding muscles and (d) the obliquity of the neck of femur.
- The trochanteric line of the femur is said to be caused by the pull of the massive iliofemoral ligament.
- The psoas bursa communicates with the joint cavity rarely in very young people but commonly in adults.
- The diameter of the acetabular labrum is less than that of the femoral head, thus preventing slipping out of the latter from inside the acetabulum.
- During extension, after the femur has passed 10 to 15 degrees behind the vertical, no further extension is possible. This is where the articular surfaces are closely packed (and congruent to a large extent) and all the major ligaments are taut; the joint is then said to be ***locked***.
- In the erect position, the line of centre of gravity of the trunk falls behind the line joining the two heads of femora. Hence, the pelvis tends to roll back but is prevented from doing so by the locking of the hip.

Comparison between Hip and Shoulder

The hip joint has several similarities with the shoulder joint. The depth of the acetabulum is increased by the acetabular labrum, similar to the glenoidal depth being increased by the glenoidal labrum. However, the difference between the two joints is more striking. The acetabulum is a much deeper cavity than the glenoid cavity. As a result, the adaptation of the head of the femur with the acetabulum is far more intimate than that of the head of the humerus with the glenoid cavity. This results in the hip joint being more stable and less mobile than the shoulder joint.

The fibrous capsule of the hip is stronger. In full extension it becomes very tense. This is in contrast to the thin and lax capsule of the shoulder.

The controlling muscles of the hip are inserted at some d stance from the centre of movement.

Clinical Correlation

***Referred pain*:** The femoral nerve that supplies the joint, also supplies the skin of the front and medial side of thigh. So, pain originating in the hip may be referred to the front and medial side of thigh. The posterior division of the obturator nerve supplies both the hip and the knee. So, hip joint disease can give rise to pain in the knee.

Pain in the region of hip may be referred from the umbo-sacral spine

***Dislocations of hip*:** All parts of the fibrous capsule are relaxed when the hip is flexed. So, most dislocations tend to occur then.

- ***Congenital dislocation*** occurs more commonly in the hip than any other joint. In the ***hypoplastic type of congenital dislocation***, the upper lip of acetabulum is poorly developed and the head of femur rides up to the gluteal surface of ilium. This condition is more common in female children than males. In the lax type, the joint capsule is very loose at birth, leading to separation of the ball and the socket. ***Traumatic dislocations*** are rare due to the extreme strength of the joint. They occur in motor vehicle accidents or in falls from a height. These dislocations may be accompanied by fracture of the femur and can be posterior, anterior, or central.
- In ***posterior dislocation***, the head of the femur passes backwards and rests on the gluteal surface of ilium. The rim of the acetabulum is usually fractured. The limb is medially rotated. There is serious danger of injury to the sciatic nerve which lies just behind the joint.
- ***Anterior dislocation*** is not common. It is caused by forced abduction and lateral rotation of the limb. The limb is laterally rotated.
- In ***central fracture dislocation***, the head of the femur breaks through the floor of the acetabulum to enter the pelvic cavity. There is great danger to the sciatic nerve in this dislocation.

  The traditional Indian way of carrying children on the mother's waist places the hip joints of the child in a position of flexion abduction and lateral rotation. This accords natural protection against a possible congenital dislocation:

Trendelenburg's sign*:** When a person stands on one leg and raises the other, the stability of the hip joint on the supported side depends on—(a) normal functioning of gluteus medius and gluteus minimus, (b) normal location of the femoral head inside the acetabulum and (c) intact neck of femur. As a result, pelvis on the unsupported side is raised. If any one of these factors is defective (as in dislocated femoral head, fractured femoral head or neck, injury to superior gluteal nerve), the pelvis on the (opposite) unsupported side sinks. This is called the ***positive Trendelenburg's sign.

Arthritis*:** Inflammation of the hip causes increased synovial secretions. The excess fluid gets collected within the joint cavity. The patient tends to place the thigh in a position of minimal discomfort—the position where the joint can accommodate the excess fluid—the position of partial flexion, abduction and lateral rotation. ***Osteoarthritis, the most common disease of

contd...

Clinical Correlation *contd...*

the hip joint in adults, causes pain, stiffness and subsequently, deformity. The deformity is flexion, adduction and lateral rotation and is caused by muscle spasm in the initial stages and by muscle contractures later.

***Fractures of the neck of femur*:** These are common in the older age group, especially in women. The neck of femur becomes weak and brittle due to osteoporosis and is liable for a break. Hence, even trivial injuries cause such fractures. Since part of the neck is extracapsular and part of it is intracapsular, very often the fractures are intracapsular and treatment becomes complicated. The retinacula are damaged during neck fractures and in turn, the retinacular arteries. The intracapsular fractures can be close to the articular margin of the head (subcapital) somewhere in the middle of the neck (middle cervical) or close to the root of the neck (basal).

***Avascular necrosis of head of femur*:** The head of femur receives blood supply through three sets of arter es These are—(a) the retinacular arteries—branches from them perforate the neck of femur, just distal to the head and then run towards the centre of the head, (b) terminal branches of the nutrient artery of the shaft, and (c) the artery of the ligament of the head. The supply from the last source is scanty and the supply from the second source does not reach the central part of the head. When the neck of femur fractures, the retinacular branches are damaged; total blood supply, inspite of a few anastomoses between the various sources, is poor to sustain viability of the femoral head and ischemic necrosis takes place gradually. Subcapital intracapsular fractures cause greatest damage to the retinacular arteries and basal fractures the least.

***Perthe's disesse*:** This is a condition of temporarily insufficient blood supply to the head of femur, thus leading to destruction and flattening of the head. The reason for poor blood supply is not known and very often, as growth proceeds, arterial anatomoses take over. However, bony growth is not uniform and normal and so some amount of deformity continues.

***Coxa valga and vara*:** The neck of femur is inclined at an angle to the shaft. The angle between the two is about 125 degrees in adults and about 160 degrees in children. Increase in this angle causes coxa valga and decrease causes coxa vara. Coxa valga limits adduction of the hip and can be seen in congenital dislocation of hip; coxa vara limits abduction and is seen in fractures of neck of femur.

Lines of importance:

- ***Nelaton's line***: Passes from anterior superior iliac spine to ischial tuberosity and touches the highest point of greater trochanter. In fracture or dislocation, greater trochanter is displaced upwards.
- ***Shenton's line***: Is a continuous curve of the lower border of neck of femur and upper border of obturator foramen seen in X-rays. In fractures and in dislocations, it is not a continuous curve and is disrupted.
- ***Schoemaker's line***: A straight line joining the tip of greater trochanter, anterior superior iliac spine and umbilicus. In fractures, this line passes below the umbilicus.
- ***Bryant's triangle***: An imaginary triangle drawn with the patient supine. Line 1 is a vertical line from the anterior superior iliac spine to the bed; line 2 is a horizontal line

contd ..

Clinical Correlation *contd...*

from tip of greater trochanter to line 1; line is from anterior superior iliac spine to the tip of greater trochanter. Fractures and dislocations cause the triangle to go out of shape.

***Joint replacement*:** In old age the articular surfaces of the hip joint often undergo degeneration due to osteoarthritis. Movements get restricted and there is pain. The condition can be corrected by replacing the joint with one made of artificial materials.

KNEE JOINT

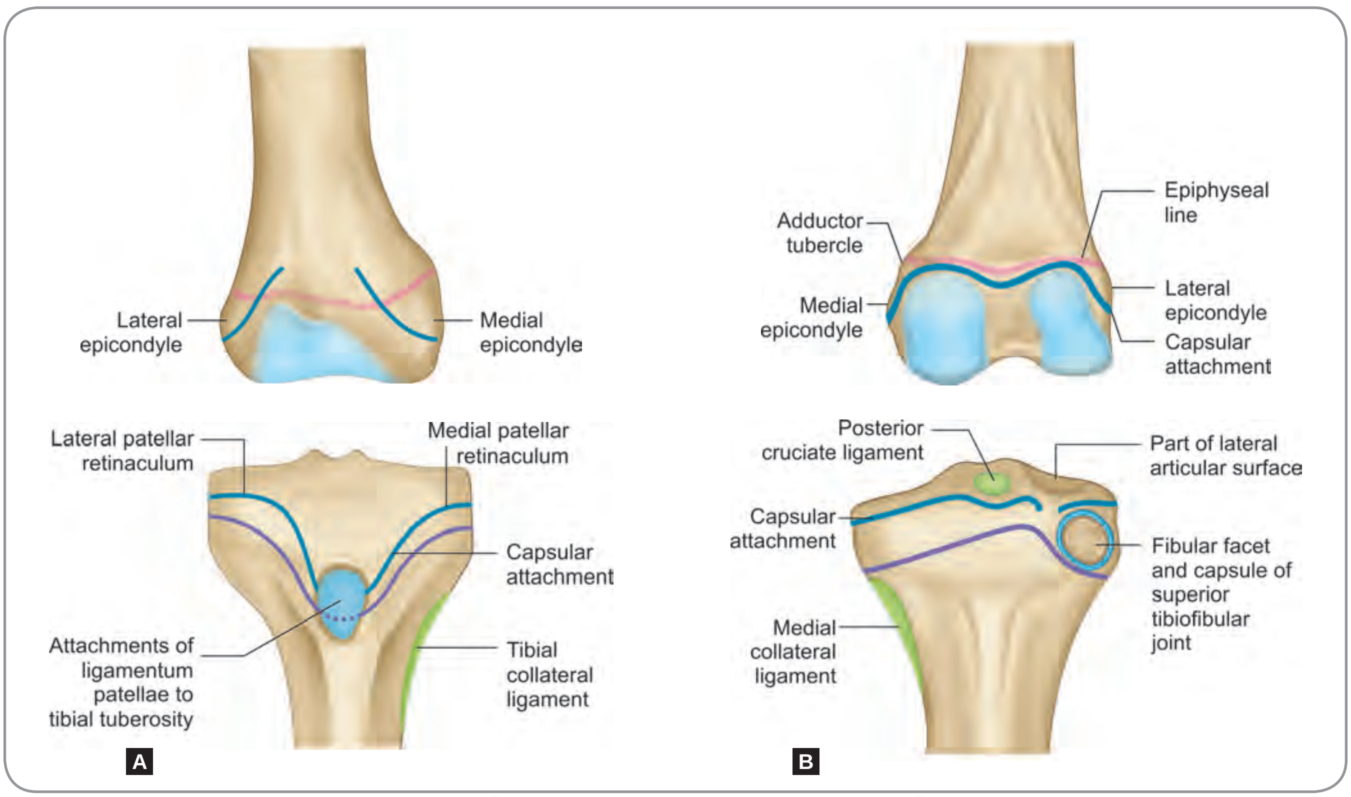
The knee joint (or the ***genual joint*** or the ***stifle joint***) is the largest and most complicated joint of the human body. It actually has three joints, namely—(1) the right femorotibial, (2) the left femorotibial and (3) the femoropatellar joints. Fibula is not directly involved in the knee joint. When compared to other joints, the knee is also very superficially placed.

It is a uniaxial synovial joint. It has two articular surfaces on the medial and lateral condyles of the femur (Figs 29.8A, and B), for articulation with corresponding surfaces on the medial and lateral condyles of the tibia, thereby forming the two femorotibial joints which are of the condylar (functionally, a hinge with flexion-extension movements around the transverse axis) variety. The anterior aspect of the lower end of the femur articulates with the posterior aspect of the patella forming the femorapatellar joint which is of the sellar (functionally a gliding joint where patella glides over the femoral trochlea) variety The femorotibial joints are weight-bearing and the femoropatellar joint functions as a major component of the quadriceps mechanism.

It is customary to call the knee, a compound joint because of the involvement of more than two articular bony elements (femur, tibia and patella). It is also a complex joint (or a combination joint or a composite joint) because two separate bony joints (femorotibial joint and the femoropatellar joint) are merged into a single functional entity.

Articular Surfaces

The articular surfaces are large and have complicated shapes. The joint is marked by incongruence (reciprocal areas do not correspond in shape and size to one another). However, two fibrocartilaginous structures called the ***menisci*** (singular meniscus) contribute to changes in the shape of the articular surfaces during joint movements and aim at better congruence. All the three joints put together, the articular surfaces can be described as—(1) proximal, (2) distal and (3) ventral All of them are enclosed within a single joint cavity.



Figs 29.8A and B: Attachment of capsule of the knee joint **A.** Anterior aspects of the femur and tibia **B.** Posterior aspects of the femur and tibia

- The ***proximal (or femoral) articular surfaces*** cover the anterior, inferior and posterior aspects of the medial and lateral condyles of the femur. Anteriorly, the surfaces on the medial and lateral condyles are continuous with each other but posteriorly they are separated by the intercondylar notch. The proximal articular surface can further be subclassified as the tibial surface and the patellar surface. The tibial articular surface of each femoral condyle is convex anteroposteriorly, the curvature being much more marked in the posterior part. This is most obvious when the condyle is viewed from the side. The condyles are also convex from side-to side. The lateral condylar articular surface is straight, less curved and smaller by about 2 cm than its medial counterpart. The medial condylar surface shows an anteroposterior curve, the convexity of the curve being directed medially; it is longer and obliquely placed. The patellar (or the trochlear) surface is situated on the anterior aspect of the lower end of femur. It is concave from side-to-side and is subdivided by a vertical groove into a larger lateral part and a smaller medial part. A small part of the inferior surface of the medial condyle, adjacent to the anterior part of the intercondylar notch comes in contact with the patella in extreme flexion of the knee. The area for the patella is marked off from the area for the tibia on each condyle by a slight groove.

The articular capsule is reinforced anteriorly by medial and lateral patellar retinacula, on the medial aspect by the tibial collateral ligament, posteriorly by the oblique popliteal ligament, expansions from the Sartorius and semimembranosus and the iliotibial tract.

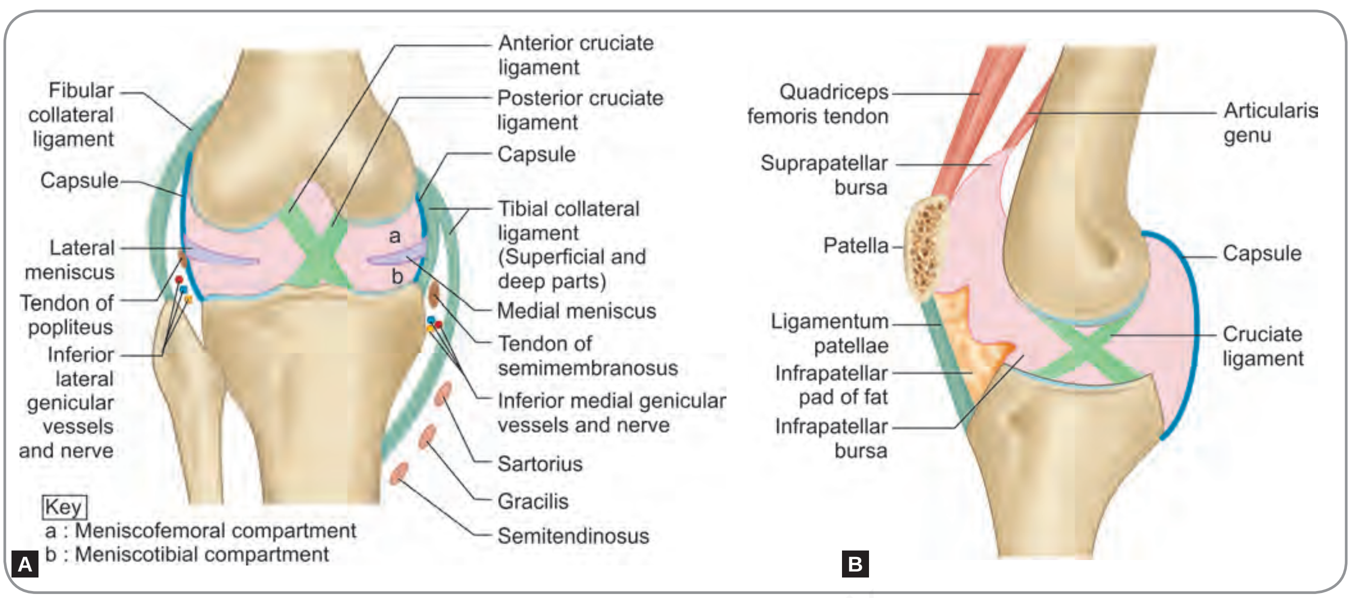
- The ***distal (or tibial) articular surfaces*** of the knee joint are present on the upper surfaces of the medial and lateral condyles of the tibia, separated by a rough non-articular area called the ***intercondylar area of tibia***. These surfaces are slightly concave centrally, and flat at the periphery, where they are covered by the corresponding menisci. The articular surface of the medial condyle is oval, its anteroposterior diameter being greater than the transverse diameter. The articular surface of the lateral condyle is almost circular. The posterior part of this surface is rounded and can be seen from behind; the tendon of the popliteus muscle glides over this area.
- The ***ventral articular surface*** is a large articular area for the femur present on the posterior surface of the patella. It is convex and is divided by a ridge into a larger lateral part and a smaller medial part. Near the medial margin of the patella the articular area has a narrow semilunar strip that comes in contact with the medial condyle of the femur only in full flexion.

Articular Capsule

The attachments of the capsule of the knee joint are complicated because of the presence of the patella anteriorly, and because the capsule blends indistinguishably with the lower tendinous part of the quadriceps femoris muscle. The capsule, therefore, is often described to be deficient anteriorly and is replaced from above downwards by the quadriceps, the patella and the ligamentum patellae

Attachments on the Femur (Superior Attachment)

- On the medial side of the femur, the capsule is attached to the medial and posterior aspects of the condyle just beyond the articular surface.



Figs 29.9A and B: Knee joint **A.** Coronal section **B.** Sagittal section

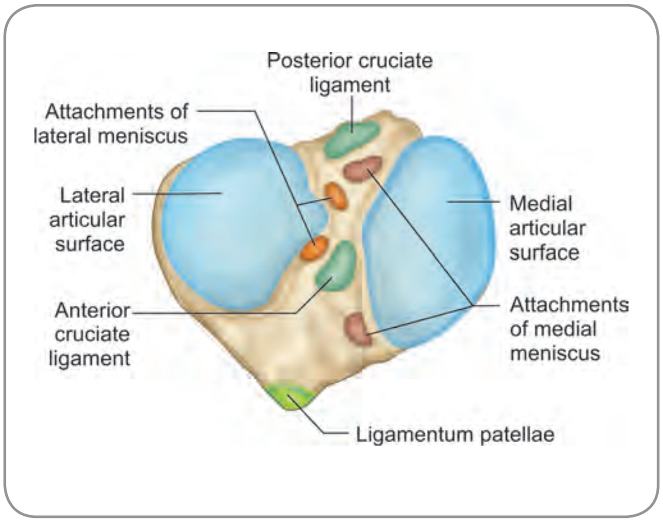


Fig. 29.10: Upper end of right tibia to show attachments

- Traced laterally, the line of attachment passes along the posterior margin of the intercondylar notch to the posterior surface of the lateral condyle (thereby making the intercondylar fossa intracapsular) and then to the lateral side of the condyle where it is attached above the origin of the popliteus muscle (Fig. 29.9A).
- Anteriorly, the capsule merges with expansions from two muscles, namely—(1) the vastus medialis (medially) and (2) the vastus lateralis (laterally). These expansions are attached to the upper, lateral and medial borders of the patella; and below the patella to the medial and lateral sides of the ligamentum patellae (Fig 29.9B).

Attachments on the Tibia (Inferior Attachment)

- On the medial side, the capsule is attached to the medial margin of the medial condyle of the tibia.
- Traced posteriorly, the line of attachment passes (in that order) onto the posterior aspect of the medial condyle, the posterior margin of the intercondylar area, the posterior and then the lateral margin of the lateral condyle.
- There is a gap in the capsular attachment behind the lateral condyle. The popliteus, which arises from within the knee joint, leaves it through this gap. Here the lower margin of the capsule is attached to a band of fibres called the ***arcuate popliteal ligament***.
- Anteriorly, the expansions from the vastus medialis and the vastus lateralis gain attachment to the anterior aspect of the medial and lateral condyles of the tibia—here these expansions are called the ***medial and lateral patellar retinacula***.

Ligaments

The knee joint is strengthened by many ligaments. As it is natural to a hinge joint, two strong collateral ligaments are present. In addition to ligaments which lie outside the joint or are thickenings in the capsule, there are also ligaments inside the joint cavity. It is usual to classify the ligaments of the knee into the ***extracapsular*** or external ligaments and the ***intracapsular*** or internal ligaments.

The extracapsular ligaments are:
- Tibial collateral ligament;
- Fibular collateral ligament;
- Ligamentum patellae;
- Oblique popliteal ligament;
- Arcuate popliteal ligament.

The intracapsular ligaments are:
- Cruciate ligaments;
- Menisci;
- Transverse (anterior) ligament of knee;
- Meniscofemoral ligaments;
- Coronary ligament.

> Tibial collateral ligament is related superficially to the tendons of sartorius, gracilis and semitendinosus. On its deeper aspect are the inferior medial genicular artery and nerve. However, the important thing to be noted is that the medial meniscus is attached to the deeper aspect of TCL.

- ***Tibial collateral ligament (medial collateral or medial ligament)*** (Fig. 29.9A): It is a strong, broad flat band of fibres present on the medial aspect of the joint. It is truly a thickening of the capsule and hence, often called an intrinsic ligament of the joint. It is attached above to the medial epicondyle on the medial surface of the medial condyle of the femur just below the adductor tubercle. Inferiorly, it has a deep and a superficial part. The deep fibres are attached to the articular margin of the medial condyle of the tibia—they are adherent to the medial meniscus and blend with the capsule. The anterior and more superficial fibres gain attachment to the upper part of the medial surface of the shaft of the tibia. They are separated from the capsule by an expansion from the semimembranosus, and by the medial inferior genicular vessels and nerve

> Morphologically, the TCL represents the lower part of the adductor magnus muscle.

- ***Fibular collateral ligament (lateral collateral or lateral ligament or the long external lateral ligament):*** It is a rounded, cord-like band that lies on

the lateral aspect of the joint. It does not blend with the capsule and stands out separately. Hence, it is often called the ***extracapsular ligament*** It is attached above to the lateral epicondyle of the femur above the groove for the popliteus. Below it is attached to the lateral aspect of the head of fibula. The ligament is separated from the lateral meniscus by the tendon of the popliteus and is, therefore, not adherent to the meniscus. At its inferior attachment, the ligament splits the tendon of biceps femoris. The inferior lateral genicular vessels and nerves also lie deep to the ligament.

Morphologically, the FCL represents the upper part of the peroneus longus.

Fibular collateral ligament is related superficially to the Biceps femoris tendon. On its deeper aspect is the Popliteus tendon and the inferior lateral genicular artery and nerve.

- ***Functions of the collateral ligaments:*** Both the collateral ligaments are taut in extension of knee

- ***Ligamentum patellae (or patellar ligament):*** It is a strong and thick fibrous band extending from the apex of patella to the tibial tuberosity. It is actually a continuation of the quadriceps femoris tendon and replaces the articular capsule below the patella. This ligament is attached above to the nonarticular lower part of the posterior surface of the patella and below to the upper smooth part of the tibial tuberosity. Some of its fibres may extend onto the lower rough part of the tuberosity. On either side, the ligament is continuous with the patellar retinacula. It acts as the anterior ligament of the knee joint.

The patellar ligament is related to the large mass of infrapatellar pad of fat and the deep infrapatellar bursa on its deeper aspect.

- ***Oblique popliteal ligament:*** It is a broad band that blends with and strengthens the joint capsule on the posterior aspect. This ligament is an expansion from the tendon of the semimembranosus. It passes upwards and laterally from the posterior aspect of the medial condyle of the tibia to be attached to the femur on the lateral part of the intercondylar line and to the lateral condyle. It forms part of the floor of the popliteal fossa and the popliteal artery lies in close contact (posterior to the ligament). Middle genicular artery, middle genicular nerve and the genicular branch of the obturator nerve pierce this ligament.
- ***Arcuate popliteal ligament:*** This ligament strengthens the capsule on the posterolateral aspect It is 'Y' shaped and is sometimes called the ***short lateral ligament of the knee joint***. The stem of the 'Y' is attached to the head of fibula. One of the limbs arches over the emerging tendon of popliteus and is attached to the posterior margin of the intercondylar area of tibia. The other limb extends to the lateral epicondyle of femur, deep to the fibular collateral ligament.

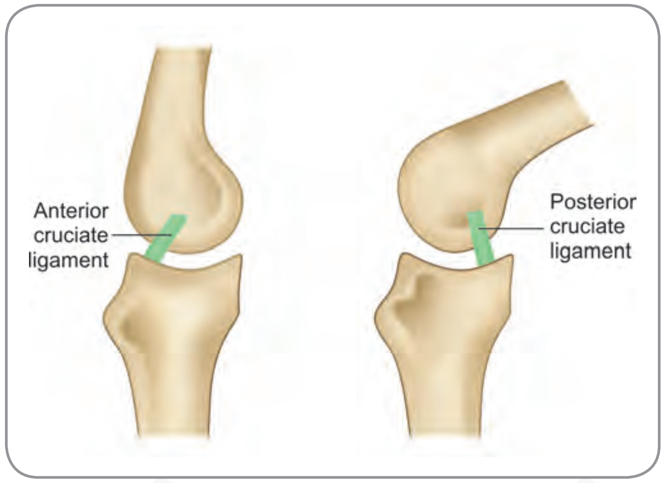


Fig. 29.11: Anterior and posterior cruciate ligaments; Note anterior cruciate ligament is taut during knee extension and posterior cruciate ligament during knee flexion

- ***Cruciate ligaments*** (Fig. 29.11): (Latin.cruciate=cross); These are two ligaments present inside the articular or joint cavity. They are short bands in the centre of the joint, crossing one another in the sagittal plane and hence the name. They bind the femur and the tibia and keep the two bones close to each other. They are named anterior and posterior depending on their attachment to the tibia.
  - ***Anterior cruciate ligament:*** Its tibial end is attached to the anterior part of the intercondylar area of tibia, between the anterior horns of the medial and lateral menisci. The femoral end is attached to the posterior aspect of the medial surface of the lateral condyle of femur. Therefore, the direction from tibial to femoral end is upwards, backwards and lateral It is the key stabilizer of the knee joint. It limits posterior dislocation of femur on the tibia and so prevents hyperextension of the joint. It also prevents anterior dislocation of tibia on the femur. It is the weaker of the two cruciate ligaments (Fig. 29.11).
  - ***Posterior cruciate ligament:*** It is the stronger of the two cruciate ligaments, and has its tibial end attached to the posterior part of the intercondylar area. The femoral end is attached to the anterior aspect of the lateral surface of the medial condyle of femur. The direction from tibial to femoral is upwards, forwards and medial. It is the key stabiliser of the joint when it is flexed and weight bearing It

prevents anterior dislocation of femur on tibia and posterior dislocation of tibia on femur also limits hyperflexion of the joint (Fig. 29 11).

- ***Menisci:*** These are two crescentic plates of fibrocartilages (Greek.meniskos=crescent) present on the articular surfaces of tibia They are called the ***medial and lateral menisci*** (or ***semilunar cartilages***). They deepen the articular surfaces of tibia, thus enhancing congruence between the femoral and tibial surfaces. Wedge shaped in transverse section, they have a thick peripheral border and a thin inner border. By their anterior and posterior ends (called the anterior and the posterior horns or cornua), the menisci are attached to the tibial intercondylar area. Both the menisci also function as shock absorbers of the joint and provide lubrication. When the knee is extended, the menisci rest on the groove in femur separating the tibial and patellar articular areas.
  - ***Medial meniscus*:** This is a C-shaped structure; it is broader posteriorly than anteriorly. The anterior horn (cornu) is attached to the anterior intercondylar area anterior to the anterior cruciate ligament and the posterior horn attached to the posterior intercondylar area anterior to the posterior cruciate ligament. Its periphery is firmly adherent to the fibrous capsule and the tibial collateral ligament. This fixing makes the medial meniscus less mobile and more prone to injuries (Fig. 29 12).
  - ***Lateral Meniscus*:** This is circular in shape, thereby causing the two horns to be close to each other. The anterior horn is attached to the anterior intercondylar area, posterior to the anterior cruciate ligament and the posterior horn attached to the posterior intercondylar area, anterior to the medial meniscal attachment. Infact, the two attachments are just in front of and behind the intercondylar eminence. The tendon of popliteus intervenes between the lateral meniscus and the fibrous capsule. As the tendon passes posterior to the meniscus, it grooves the meniscus and some fibres of it are attached to the posterior horn. The periphery of lateral meniscus is practically unattached to the fibrous capsule except for a very few lax fibres. Hence. Lateral meniscus is more mobile (than its medial counterpart) (Fig. 29.12).

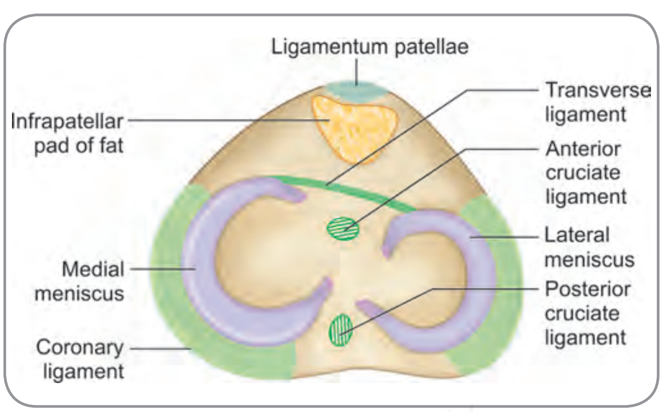


Fig. 29.12: Medial and lateral menisci of the knee joint

- ***Transverse ligament of knee*:** This is a band of fibres that connects the anterior horns of both the menisci and so is an intracapsular structure.
- ***Meniscofemoral ligaments*:** These are two ligaments that connect the posterior horn of lateral meniscus to the medial condyle of femur. They run in front of and behind the posterior cruciate ligament and attach to the medial condyle of femur just in front of and behind the femoral attachment of posterior cruciate higament. The anterior is often called the ***ligament of Humphrey*** and the posterior, the ***ligament of Wrisberg.*** They provide fixity to the posterior horn of the lateral meniscus and control its movements.
- ***Coronary ligaments*:** These are parts of the fibrous capsule which provide attachments to the peripheral margins of the medial and lateral menisci. On the deeper aspect of the fibrous capsule, there are short fibres which connect the peripheral margins of the medial and lateral menisci to the medial and lateral condyles of the tibia respectively. They provide anchorage to the menisci. However, the lateral coronary ligament is present only in the anterior aspect and is very weak and lax. On the contrary, the medial coronary ligament extends for most of the margin of the medial meniscus and tends to anchor it firmly. This anchorage of the medial meniscus can result in more injuries to the meniscus.

Dissection

Identify the sartorius, gracilis and semitendinosus muscles. Detach them from their tibial attachments and reflect upwards. The tibial collateral ligament can now be seen. Similarly, identify the biceps femoris and detach it from its fibular attachment. The fibular collateral ligament is exposed. Study both the ligaments. Turning the cadaver or the free limb to the prone position, identify the remaining muscles on the posterior aspect. Detach all of them except the popliteus from their attachments so as to expose the posterior part of the joint capsule. Identify and study the oblique popliteal ligament. Identify the arcuate popliteal ligament and study its relationship to popliteus tendon. Turn the limb (or cadaver) to the supine position. Clean and define the anterior aspect of the capsule including the patella and the ligamentum patellae. Make a transverse incision above the patella through the quadriceps. Make vertical incisions down the sides of the knee from the medial and lateral tips of the transverse incision. The patella and the ligamentum patellae can now be reflected downwards. Study the internal structures including the cruciate ligaments by alternately flexing and extending the joint

Synovial Membrane

The synovial membrane of the knee joint covers all structures within the joint cavity (or the articular cavity, which is the space containing the synovial fluid) except the articular surfaces and the surfaces of the menisci (which are surfaces covered by articular cartilage). Hence it is very extensive and complicated.

It is attached to the margins of patella, since the posterior aspect of patella is covered with articular cartilage. From the upper margin of patella, due to a deficient capsule in this part, the synovial membrane extends upward deep to the quadriceps femoris (which actually is the replacement for the capsule here) to form the ***suprapatellar bursa***. At the lower end of the suprapatellar bursa, the membrane gets attached to the articular margins of the anterior articular surface of femur. From the medial and lateral margins of patella, the synovial membrane lines the inner aspects of the medial and lateral patellar retinacula and continue to line the joint capsule. Above and below, as it reaches the point of attachment of the capsule to the concerned bone, it takes a turn to cover whatever portion of the bone that lies within the capsule and then proceeds to get attached to the articular margin on that bone.

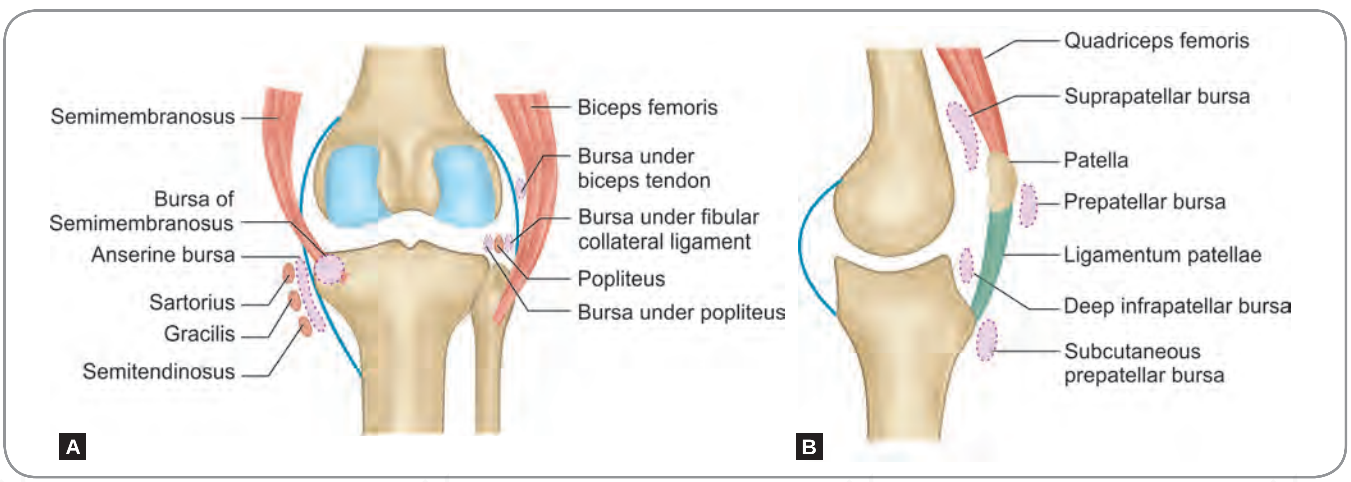
Below the apex of patella, the synovial membrane extends deep to the ligamentum patellae which is the replacement to the joint capsule. However, the relationship between the membrane and the ligament is not a mere lining of the latter by the former and is altered due to the presence of the infrapatellar pad of fat. The infrapatellar pad of fat is a considerable mass of semifluid fat that conforms to the shapes of the femoral condyles and the intercondylar area. Hence, it is present more or less like a triangle with the base towards the ligamentum patellae and the apex extending as a band to the intercondylar area. The synovial membrane which is to line the ligamentum patellae is thus pushed inwards by the infrapatellar pad of fat. It assumes a similar shape as that of the pad of fat and so two fringes project into the joint cavity on either side of the ligamentum patellae. These are the alar folds. The two alar folds converge in the centre (in line with the apical extension of the fat pad) and a single extension gets attached to the intercondylar area of femur This is the infrapatellar fold or the ligamentum mucosum (Fig. 29.17).

On the posterior aspect, as is expected, the synovial membrane from its attachment to the articular margins of posterior convexities of the femoral condyles, turns to line the fibrous capsule and then attaches to the articular margins on the posterior parts of the tibial condylar surfaces and the posterior edges of the menisci. But the presence of the cruciate ligaments modifies the synovial attachments in this area. The two cruciate ligaments can be taken as invaginations into the synovial cavity. So, the synovial membrane, at the posterior central area of the capsule, turns inwards (or anteriorly) towards the intercondylar area and covers the cruciate ligaments on their sides and in front. The cruciate ligaments are not covered by the synovial membrane on their posterior aspects. The posterior central area of the capsule where the synovial membrane turns inwards is also devoid of synovial lining. On the posterolateral aspect, a small subpopliteal recess of the synovial membrane extends between the lateral meniscus and the tendon of popliteus.

Bursae around the Knee Joint

These can be classified as—(1) those communicating with the joint cavity and (2) those not communicating normally with the joint cavity (Fig. 29.13A and B).

- ***Communicating bursae:*** They are classified as:
  - ***Suprapatellar bursa:*** This, as already seen, is a large extension of the joint capsule on the superior aspect. It lies between the shaft of femur posteriorly and the quadriceps femoris muscle anteriorly. The apex (superior end) of the bursa receives fibres of the articularis genu muscle. The muscle fibres contract



Figs 29.13A and B: Bursae around the knee joint **A.** Bursae on the medial and lateral aspects of the knee **B.** Bursae on the front of the knee

during extension of the knee and thus pull the bursa away from the knee, also preventing it from getting caught between bony surfaces
- ❍ ***Popliteus bursa:*** The subpopliteal recess, if a little large, is described as the popliteal bursa and is communicating with the cavity.
- ❍ A bursa usually lies between the medial head of gastrocnemius muscle and the posterior aspect of the fibrous capsule. This is called the ***Brodie's bursa*** and communicates with the joint cavity.
- ❍ A bursa lies between the tibial collateral ligament and the insertions of sartorius, gracilis and semitendinosus. It is the ***anserine bursa*** or bursa anserinus and is communicating with the joint cavity.

❑ ***Non-communicating bursae:*** These can be further subclassified , depending upon their locations into the anterior group, medial group and the lateral group.
- ❍ ***Anterior group—***
  - ***Subcutaneous prepatellar bursa*****:** This is between the lower part of patella and the skin overlying it.
  - ***Subcutaneous infrapatellar bursa*****:** This is between the ligamentum patellae and the overlying skin.
  - ***Deep infrapatellar bursa*****:** This is between the ligamentum patellae and the tibial tuberosity.
- ❍ ***Medial group—***
  - ***Intertibial bursa*****:** This is between the superficial and deep parts of the tibial collateral ligament.
  - ***Semimembranosus bursa*****:** This is between the insertion of semimembranosus and the medial condyle of tibia. It may sometimes communicate with the joint cavity.
- ❍ ***Lateral group—***
  - ***Lateral gastrocnemius bursa*****:** This is between the lateral head of gastrocnemius and the joint capsule.
  - ***Biceps bursa*****:** This is between the tendon of biceps femoris and the fibular collateral ligament.
  - ***Lateral popliteal bursa*****:** This is between the popliteus tendon and the fibular collateral ligament.

Relations

Anterior: Tendon of quadriceps tendon, the ligamentum patellae and the medial (anteromedially) and lateral (anterolaterally) patellar retinacula

Posteromedial: Tendons of semimembranosus (along with semitendinosus), gracilis and sartorius, medial head of gastrocnemius.

Posterolateral: Tendon of biceps femoris, common peroneal nerve, lateral head of gastrocnemius and plantaris.

Posterior: Closest posterior relation is the popliteal artery. Popliteal fossa and its contents form the poster or relations. The popliteal artery and the tibial nerve running on the oblique popliteal ligament between the two heads of gastrocnemius will have to be remembered specifically.

Arterial Supply

The knee joint derives abundant blood supply from an intricate, complex anastomosis that is formed around the joint.

- ❑ Medial superior, medial inferior, lateral superior and lateral inferior genicular branches of the popliteal artery;
- ❑ Twigs from the descending genicular branch of the femoral artery and the descending branch of lateral circumflex femoral artery;
- ❑ Circumflex fibular branch of the posterior tibial artery;
- ❑ Recurrent branches of the anterior tibial artery and
- ❑ Middle genicular artery—form the arteries of supply to the knee.

The ***medial superior*** passes deep to the tendon of adductor magnus and reaches the anterior aspect; the ***medial inferior*** passes deep to medial head of

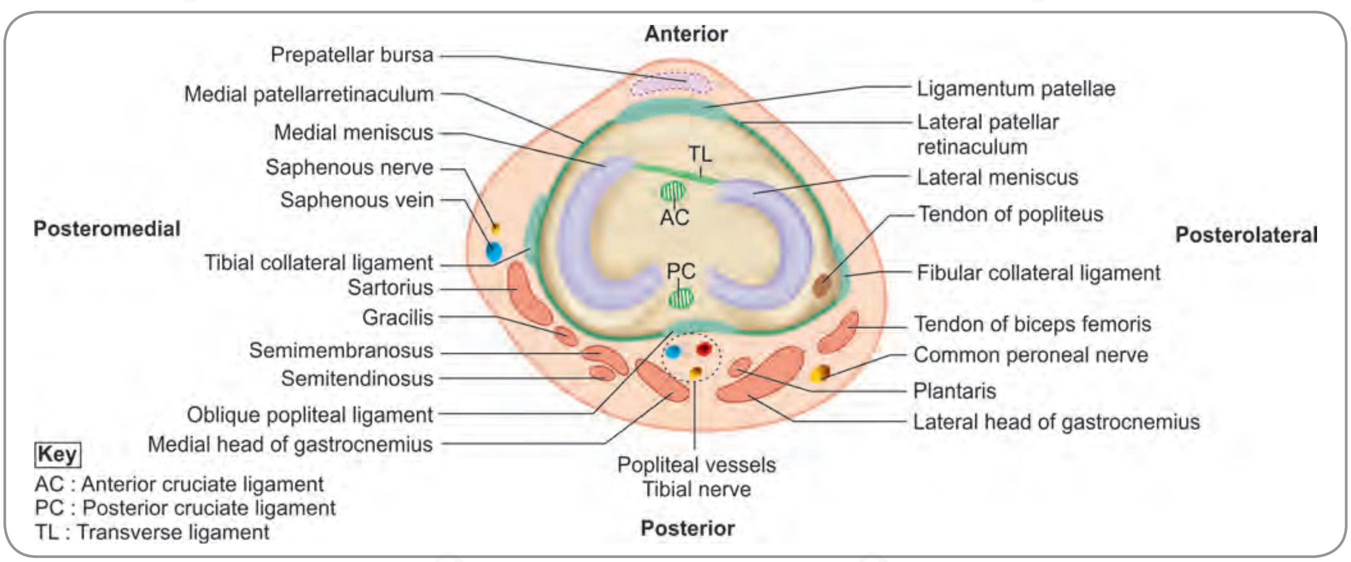


Fig. 29.14: Relations of the knee joint (transverse section of right knee joint)

gastrocnemius and then the tibial collateral ligament to reach the anterior aspect; the ***lateral superior*** passes deep to the biceps femoris tendon and reaches the anterior aspect; the ***lateral inferior*** runs across the popliteus muscle, then deep to lateral head of gastrocnemius and fibular collateral ligament to reach the anterior aspect. Once reaching the anterior aspect, each of these genicular arteries divides into two branches—(1) the branches anastomoses with its fellow of the opposite and (2) with the fellow of the same side. Thus, a square shaped network with a superior horizontal, an inferior horizontal, a medial vertical and a lateral vertical component is formed. The superomedial end of the square receives the deep branch of the descending genicular branch of the femoral artery. The superolateral end of the square receives the genicular twig of the descending branch of the ***lateral circumflex femoral artery***. The inferolateral part of the square receives the ***circumflex fibular branch of the posterior tibial artery*** and the anterior tibial recurrent branch of the anterior tibial artery. Multiple branches arise from this square anastomosis and supply the knee joint. In addition, the ***middle genicular branch of the popliteal artery*** (it does not take part in the anastomosis) pierces the oblique popliteal ligament and enters into the joint. The posterior tibial recurrent branch of the anterior tibial artery, if present, also supplies the posterior aspect of the joint.

Nerve Supply

The articular branches of the femoral, obturator, tibial and common peroneal nerves supply the knee joint. Articular twigs of the femoral are given out from the genicular branch of the saphenous nerve and the nerves to the three vasti. The obturator component is the descending articular branch of its posterior division. The tibial nerve supplies through its superior medial genicular, inferior medial genicular and the middle genicular branches. The common peroneal nerve, in the popliteal fossa, gives two genicular branches, namely—(1) the superior lateral and (2) the inferior lateral; also, it gives a recurrent genicular branch.

Movements

The main movements at the knee joint are those of flexion and extension. However, these movements are not simple and the knee is often called the ***modified hinge***.

- The axis around which flexion-extension occurs is the transverse axis. However, in the knee joint, the axis does not rema n fixed. Because of differences in the convexity of the anterior and posterior parts of the femoral condyles, the axis of movement shifts forward during extension and backwards during flexion
- The tibia and menisci glide forward relative to the femoral condyles in extension; and backwards in flexion.
- The last moments of extension are associated with rotation. As a corollary, the initial moments of flexion are associated with rotation.
- During ***flexion-extension movements***, the femoral condyles move on the tibiomeniscal surfaces and so the movements occur in the meniscofemoral compartment
- During rotation, movements occur around a vertical axis and the movements occur in the meniscotibial compartment (Table 29.2).

At flexion, small areas of the femoral condyles and the tibial condyles are in contact. When the joint is extended, the femoral condyles roll and glide on the tibial condylar surfaces, gradually increasing the areas of contact. The lateral condyles are smaller and so reach complete contact (***used up*** completely) earlier. The medial condyles still have some area left out (***unused***) and so the articular surfaces are not in total congruence. This position of ***extension*** (or

Table 29.2: Movements of the knee joint

Movement	Muscles producing	Factors limiting
Extension	Quadriceps femoris (all four components); assisted by tensor fascia latae through the iliotibial tract	Tension in the anterior cruciate ligament; Also tension in the tibial and fibular collateral ligaments, the hamstrings and the gastrocnemii
Flexion	Hamstring muscles (all of them including the hamstring part of adductor magnus); assisted by popliteus, gracilis and sartorius, gastrocnemius and plantaris	Tension in the posterior cruciate ligament; and also in the anterior part of the tibial collateral ligament and the quadriceps femoris; contact with the posterior aspect of thigh
Medial rotation (of flexed leg) – adjunct rotation	Popliteus, semimembranosus, semitendinosus assisted by sartorius and gracilis	Contact between adjacent structures and build up of tension in the ligaments and muscles
Lateral rotation (of flexed leg) – adjunct rotation	B ceps femoris	Contact between adjacent structures and build up of tension in the ligaments and muscles

pre-extension, as called by some) is sufficient when the individual is walking or running. However, while standing (which is the weight-bearing position), the knee is not stable in this level of extension, since the condyles are not congruent. At the same time, simple extension cannot proceed further, because the femoral condyles are already at the anterior parts of the tibial surfaces. Medial femoral condyle moves backwards (that is, medial rotation of femur occurs) in an arc; this leaves free space on both femoral and tibial medial condyles; further extension now takes place, bringing the medial condyles into full congruence. The joint attains a position of stability. ***Medial rotation*** of femur in the final stages of extension and subsequent further extension of the knee together lead to ***locking of the knee*** or the ***screw-home*** movement. The axis for this medial rotation passes through the head and lateral condyle of femur.

For flexion to occur from the fully extended and locked position of the joint, medial rotation of the femur has to be first undone. This is unlocking of the joint. Popliteus rotates the femur laterally and causes unlocking. Rest of the flexion then takes place.

The medial rotation of femur at the final stages of extension and a corresponding ***lateral rotation*** during early flexion, are integral parts of the ***extension-flexion*** system and hence are called ***conjunct*** rotations.

Apart from the conjunct rotations, some independent rotational movements also occur in the joint and are best seen in the semiflexed knee. These are called the ***adjunct*** rotations.

In a semiflexed knee, antero-posterior gliding of tibia on femur and little abduction-adduction can also occur passively.

Locking Mechanism

The knee joint s locked into a position of stability and weight bearing in full extension. Three important factors contribute to this mechanism. These are:

- The alteration in the shape and size of femoral surfaces that articulate on the tibial surfaces: During flexion, only the posterior parts of the condyles are in contact and these are small and so, do not give complete congruence; during extension, the inferior parts of the condyles roll and glide into contact and since these are broad, flat and larger, congruence is achieved.
- Medial rotation of the femur during the final stages of extension makes all the ligaments taut.
- Body's centre of gravity passes anterior to the knee joint and thus maintains extension.

Locking prevents any further extension or hyperextension. The same muscle that extends till lateral condylar use-up, continues to extend after medial rotation also. However, medial rotation of the femur is a passive mechanism due to bony contours and no muscular force is required to produce it. Once the knee is locked, the articular surfaces are in maximal congruence

contd…

contd…

and the ligaments are taut. Muscular force to keep the joint in position is not required and so, the quadriceps relax. This makes a person stand for hours together without strain to the quadriceps when the knee is locked and when the line of gravity travels in front of the knee.

When full extension of the knee occurs with the foot off the ground, instead of medial rotation of femur, the complimentary movement of lateral rotation of tibia occurs; lateral rotation of tibia causes locking. In flexion with the foot off the ground, medial rotation of tibia causes unlocking; popliteus acts from below on the tibia to produce unlocking.

Unlocking Mechanism

Unlocking of knee is done by popliteus at the beginning of flexion. Hence, the muscle is often called the ***key to knee*** To produce unlocking, the muscle can act either from its proximal or distal attachment. When the foot is on the ground and flexion occurs (for sitting in a chair), proximal or femoral attachment acts and there is lateral rotation of femur on the tibia. When the foot is off the ground and flexion occurs (for walking), distal or tibial attachment acts and there is medial rotation of tibia on the femur. Acting from both ends, the muscle produces unlocking. Once unlocking is achieved, the muscle continues to flex the knee.

Development

Evolutionary and embryological considerations of knee joint: In some amphibians and reptiles, the tibia and fibula articulate with the femur; three menisci intervene between them (two between the femur and tibia; one between the femur and fibula). A single cruciate ligament extends from the anterior tibial intercondylar area to the lateral femoral condyle. The menisci are almost circular and are firmly fixed to the tibia. The extensor muscle mass is inserted to the shin bone through a single ligament.

The homo sapiens is the only species where the knee joint is also weight-bearing while it is completely extended. To ensure stability during weight bearing, certain anatomical modifications happen during evolution.

- To increase the surface area of contact between the femur and the tibia and thus aid in weight bearing and stability, the femoral and tibial condyles enlarge enormously. However, to protect the neurovascular structures and to effectively focus muscular action, a deep groove is formed between the femoral condyles. The femoral condyles are thus expanded towards the popliteal space ensuring posterior stability. As a result of the expansion of the tibial condyles, the fibula (post axial bone) slips down.
- In order to stabilise an extended knee, the tibia develops a downward slope on its anterior aspect. This slope becomes the tibial tuberosity. The extensors (quadriceps) now get attached to the lower aspect of the tibial tuberosity. However, straightening of the quadriceps (compare with the knee of a quadruped where the joint is semiflexed and the quadriceps is stretched) causes a mechanical disadvantage; it has no tension for a strong effective contraction to keep the knee in continued extension. Friction of the muscle fibres leads to the formation of patella.

contd…

Development contd...

- Patella now acquires a new responsibility. Quadriceps fibres pass over the patella; this causes the required stretching in quadriceps. In a completely extended knee, patella occupies a position above the knee joint line thus adding to the stability.
- The collateral ligaments condense to form supportive structures which prevent lateral displacement. They are effective during extension but are lax during flexion. The single forerunner of the cruciate ligament divides into two which crisscross each other and provide stability during flexion and during extension under traction (cruciate ligaments are well developed in most primates who hang from tree tops and jump from branch to branch). They also act as check ligaments for rotational movements.
- The menisci are adapted for weight bearing during extension. They expand to occupy the tibial condyles and increase the area of contact between the femur and tibia. Line of weight transmission causes their internal aspects to be thinned out; this thinning increases the concavity of their superior aspects leading to increased joint congruence and accurate approximation.
- The menisci develop a fibrocartilaginous microstructure which gives them shock absorbing properties Regeneration is also possible so that smaller injuries to the menisci get repaired spontaneously.

In the 2nd month of human intrauterine life, the area of future knee joint is a dense mass of mesodermal tissue with ossifying rods of cartilage both proximal and distal to it. By the late 8th week, the fibular rod is seen separately and excluded from the joint. In the 9th week, multiple cavities appear in the dense mass by cellular death. A transverse layer of mesoderm, which is caught between the ossifying cartilaginous rods and hence called ***the interchondral disc***, is in the middle of the cavities and gives rise to the menisci. Cellular death does not occur in a vertical plane in the middle, leading to the formation of a partition; 5 joint cavities can now be discerned—(1) between future patella and future femur; (2) between the future femur and the menisci and (3) between the menisci and the future tibia. By the 4th month, two cruciate ligaments are delimited from the vertical partition; simultaneously meniscal plates are carved into crescentic pieces. These changes cause the corresponding femoromeniscal and meniscotibial joint cavities to merge. Three joints are now seen—one femoropatellar and two femorotibial joints. Further changes in the mesodermal tissue lead to a single joint cavity. The cruciate ligaments represent the ***original partition*** between the two joints. The infrapatellar pad of fat marks the lower boundary of the femoropatellar joint. The peripheral part of the mesoderm develops into the joint capsule and other ligaments. Cells f om the perichondrium of the cartilaginous rods migrate into the inner part of the mesoderm; along with the mesodermal tissue these cells give rise to the synovial membrane

Added Information

- Structurally the knee joint is weak. The articular surfaces are neither congruent nor co-extensive. The femoral condyles are large and convex; in contrast, the tibial condyles are smaller and shallow. The femoropatellar joint is equally weak; the tendency of the patella to slip laterally because of the quadriceps angle.
- Anterior cruciate ligament both the cruciate ligaments are supplied by the middle genicular artery. However, the anterior cruciate ligament has a relatively poor supply.
- The anterior cruciate ligament prevents posterior roll of the femur on the tibial plateau during flexion; instead, it converts the femoral movement into a spin.
- The posterior cruciate ligament prevents anterior roll of the femur on the tibial plateau during extension; instead, it converts the femoral movement into a spin.
- When the knee is at right angle, the tibia cannot normally be pulled anteriorly because it is held in position by the posterior cruciate ligament.
- While descending down the stairs or walking downhill, the flexed knee bears body weight; stabilization is then given by the posterior cruciate ligament.
- The anterior cruciate ligament becomes taut in extension and the posterior cruciate ligament in flexion of the knee.
- The anterior cruciate ligament is maximally taut in extension and acts as a pivotal axis for screw-home movement to take place.
- The crossing point or the chiasma of the cruciates is the pivot for the rotator movements of the knee; either of the cruciates is taut in every position of the joint, due to their obliquity.
- During medial rotation of tibia on the femur, the cruciates wind around each other; so, medial rotation is possible only for 10 degrees.
- During lateral rotation of tibia on the femur, the cruciates unwind and so lateral rotation is possible for 60 degrees.
- The menisci or the semilunar cartilages get their nutrition by diffusion from the synovial fluid except the peripheral parts which have capillary loops of the vessels of the knee joint and derive their nutrition from these capillaries.
- The presence of menisci cause the knee joint cavity to be divided into two chambers in each half (that is the ***medial*** and ***lateral halves***); the upper is the (since above the meniscus) the meniscofemoral chamber and the lower (since below the meniscus) the meniscotibial chamber. Flexion-extension occurs in the upper chamber; rotational movements occur in the lower chamber.
- Of the two menisci, the medial is more fixed by its attachment to the capsule and tibial collateral ligament; hence, it is also more prone for injury.
- The attachments of the two horns of the lateral meniscus are close to each other and so are within the attachments of the two horns of the medial meniscus.
- The attachment of popliteal tendon to the lateral meniscus is also protective. When the femur rotates laterally, the muscle pulls the meniscus back and thus prevents injury.

contd...

Added Information *contd...*

- Functionally, the menisci, apart from deepening the tibial articular surfaces, also alter the area of the tibial surfaces; as extension proceeds, instead of smaller areas, larger areas of femoral condyles come into contact with tibia; the tibial articular surfaces need to undergo alterations to accommodate the changing dimensions of the femoral condyles; such alteration is provided by the menisci which are elastic and resilient; the menisci also glide on the tibial surface to complete these alterations.
- Gliding of the menisci on the tibia are also important during rotations of the knee, when one femoral condyle moves anteriorly on its corresponding tibial surface and the other posteriorly.
- The patellofemoral joint also takes part during the movements of the knee; during extension, the upper part of the articular facet of patella is in contact with femur; during early flexion, the middle part and during continued flexion, the lower part. In the last phase of complete flexion, the medial strip in the patella comes into contact with the medial femoral condyle.
- Contact of the upper part of the patella with femur during extension is functionally important; the base of the patella is then held against the pulley made out by the femoral condyles; the patella then acts as a fulcrum for the quadriceps to keep the joint in extension.
- Stability of the knee joint depends on muscular (tone of the muscles acting) and ligamentous (integrity of the ligaments) factors; however, the most important single factor is the tone of the quadriceps muscle; this muscle can stabilize the joint even when the ligaments are torn; the ligaments of importance are the two cruciates and the two collaterals.
- While squatting, the patella can load upto six times body weight.
- While walking or going up the stairs, a load of three to four times body weight is thrust on the knee.

Clinical Correlation

- ***Dislocation of the knee joint:*** Dislocation at the knee joint is rare. It can result in damage to the popliteal artery, to the tibial nerve, or to the common peroneal nerve (especially when the dislocation is posterior).
- ***Dislocation of/injury to the patella:***
  - Injury may cause lateral dislocation of the patella.
  - Patella has a natural tendency to be displaced laterally because of the direction of pull of the quadriceps (upwards and laterally). This is prevented by the patellar retinacula; an added factor of importance is the attachment of the medial retinaculum. The level of attachment of the medial retinaculum is lower than that of the lateral retinaculum, thus making it possible for the vastus medialis to pull the patella medially.
  - In patellar fractures, leverage is lost and so extension is affected.
- ***Injuries to the soft tissues and ligaments:***
  - Injuries to the soft tissues in and around the knee are very common. Tears of the cruciates, the menisci and trauma to the collaterals can occur. The nerves and the vessels can also be injured.

contd...

Clinical Correlation *contd...*

  - Injuries in the region can lead to effusion of serous fluid into the joint cavity—***traumatic synovitis***.
  - If a blood vessel within the joint is injured, the joint can fill with blood—***haemarthrosis***.
- ***Medial meniscus tears in sports:*** Forcible extension or forcible rotation can cause tearing of the menisci. The medial meniscus is firmly attached and thus cannot adapt to a change of position. So it is frequently injured. The lateral meniscus can actually add to this injury. Its much freer and moves with the lateral femoral condyle. When it moves, it puts strain on the transverse ligament which in turn causes strain in the anterior horn of medial meniscus. Medial meniscal injury is very common in sportspersons, especially when sustaining a twisting force on a semiflexed knee (as is common in football players). A curved tear extending through the whole length of the meniscus results in what is called a ***bucket handle tear***. As the menisci have no blood supply, such tears are not accompanied by bleeding into the joint cavity.
  - Menisci are, for most part, avascular and hence do not heal.
  - Strain or tear of the medial ligament of the knee is caused by an injury that abducts the tibia on the femur. An opposite force that adducts the tibia on the femur can cause strain or tear of the lateral ligament. Abnormal degree of lateral movement of tibia in a semiflexed, non-weight-bearing knee is indicative of tibial collateral ligament rupture and abnormal medial movement is indicative of fibular collateral ligament rupture.
  - Tears of the cruciate ligaments can also occur; these do not occur in isolation and are usually accompanied by tears of tibial collateral ligament or fibular collateral ligament. A force that drives the upper end of the tibia forward can rupture the anterior cruciate ligament; and a force that pushes the tibia backwards can rupture the posterior cruciate ligament.
  - Isolated rupture of anterior collateral ligament occurs if the extended knee is twisted forcefully. Intense pain and swelling occur. Rupture of anterior collateral ligament is also often accompan ed by haemarthrosis due to injury to the blood vessels.
  - ***Anterior drawer test:*** This is done to find out rupture of anterior collateral ligament. The individual lies supine with hips and knees flexed. The ankle joint is firmly held and then the tibia is pulled forwards. Excessive forward movement of tibia is the positive anterior drawer sign. It indicates rupture of anterior collateral ligament.
  - ***Posterior drawer test:*** This is done to find out rupture of posterior collateral ligament. A similar test as above is done but here the tibia is pushed backwards. Excessive posterior movement of tibia is positive posterior drawer sign and is indicative of rupture of posterior collateral ligament.
  - ***Unhappy triad:*** This term indicates a triple injury—injury to tibial collateral ligament, to medial meniscus and the anterior collateral ligament.

Torn menisci often have to be removed. The recent technique of ***arthoscopy*** allows inspection of the interior of the knee

contd...

Clinical Correlation ***contd...***

joint, without opening it. Parts of torn menisci, or parts of other loose tissue, can be removed through the same procedure.

- Bursitis and associated conditions.
  - ***Housemaid's Knee:*** Prepatellar bursitis where the subcutaneous prepatellar bursa is inflamed and causes swelling and pain.
  - ***Clergyman's Knee:*** Infrapatellar bursitis where the subcutaneous infrapatellar bursa is inflamed and causes swelling and pain.
  - ***Baker's cyst:*** Chronic inflammation of the semimembranosus bursa causes a swelling in the medial aspect of popliteal fossa.
  - Due to the continuity between the joint cavity and the suprapatellar bursa, effusion in the knee joint fills the bursa.
- ***Degenerative diseases***

Osteoarthritis very frequently affects the knee. When the joint function is lost, ***knee replacement***, using artificial materials, is done.

- ***Runner's knee***

This is otherwise called ***patellofemoral pain syndrome***. It occurs commonly in athletes. Pain is felt near patella after sitting for a long time with knees flexed.

TIBIOFIBULAR JOINTS

The tibia and the fibula are connected by two joints, one at each end. The two bones are also connected by an interosseous membrane, which is usually described as the middle tibiofibular joint.

Proximal Tibiofibular Joint

It is a synovial joint of the plane variety, between the upper ends of tibia and fibula

Articular Surfaces and Fibrous Capsule

The proximal articular facet is on the inferior aspect of the overhanging lateral condyle of the tibia. The distal articular facet is a flat, rounded surface on the head of fibula. A fibrous capsule surrounds the joint and is attached close to the articular margins on the two bones. It is strengthened by the anterior and posterior ligaments of the head of fibula, whose fibres run superomedially from the fibula to the tibia.

Synovium and Relations

Synovial membrane lines the joint cavity. The joint is related on its posterosuperior aspect to the tendon of popliteus. The joint cavity may communicate with a synovial pouch that gets prolonged along the tendon from the knee joint

Nerve and Blood Supply

Nerve supply to the joint is by branches from the common peroneal nerve and the nerve to popliteus. Blood supply is by small arterial branches from the adjoining genicular anastomosis.

Distal Tibiofibular Joint

It is a fibrous joint of the syndesmosis variety, between the lower ends of tibia and fibula.

Articular Surfaces and Ligaments

The articular surfaces are rough and triangular and are seen on the lateral aspect of the inferior end of tibia and the medial aspect of fibula above the lateral malleolus. The two opposing surfaces are united by a strong ***interosseous ligament***, qualifying the joint to become a ***syndesmosis***. The joint is strengthened by other ligaments.

Anterior and Posterior Tibiofibular Ligaments

These are two ligaments, one on each aspect, stretching from the inferior border of tibia to the front and back of the distal aspect of fibula respectively. The fibres of both the ligaments run laterally and downwards. Under cover of the posterior ligament is the ***transverse tibiofibular ligament*** (Fig. 29.15). It is attached to the whole length of the posterior edge of the inferior surface of tibia and the malleolar fossa of the fibula This ligament closes the inferior gap between the two bones and articulates with the posterolateral part of the talar trochlea, thus participating in the ankle joint. It is considered by some as an inferior portion of the posterior tibiofibular ligament.

Though the distal tibiofibular joint is fibrous and does not have any cavity, a small recess from the ankle joint usually extends between the tibia and fibula for a short distance. The recess is blocked superiorly by the ***interosseous membrane***.

Nerve and Blood Supply

Nerve supply is by the branches of deep peroneal and tibial nerves. Blood supply is from adjacent vessels.

Middle Tibiofibular Joint

It is a joint between the two bones effected by a tight stretching of the interosseous membrane. The membrane

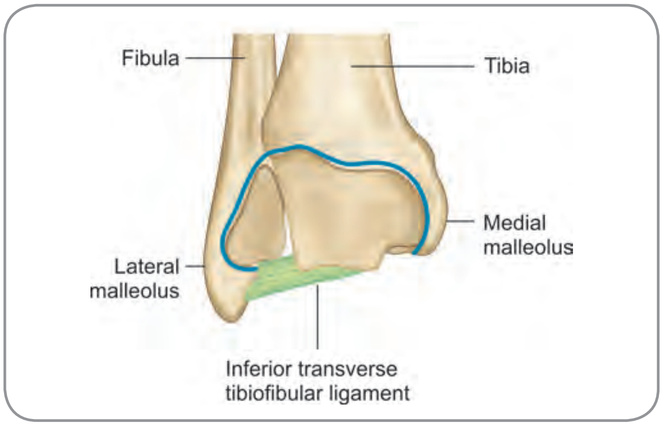


Fig. 29.15: Superior articular surface of ankle joint seen from the anteroinferior aspect

is attached to the interosseous borders of the tibia and the fibula. Its fibres run downwards and laterally from the tibia to the fibula. At the upper end, the membrane reaches the inferior aspect of the proximal tibiofibular joint and at the lower end, it blends with the interosseous membrane of the distal tibiofibular joint. The membrane has two apertures, a bigger one near the upper end for the passage of the anterior tibial vessels and a smaller one near the lower end for the passage of the perforating branch of the peroneal artery.

Movements at the Tibiofibular Joints

Very little movement is possible at these joints. However they act in unison with the ankle joint and provide essential support to movements of dorsiflexion and plantarflexion. The inferior joint provides for the spring mechanism of the grasp of talus by the tibia and fibula; its strong ligaments render support and prevent backward displacement of foot. The superior joint is capable of a small gliding movement which comes into play during walking, especially on uneven surfaces and in rapid movements of the limb.

ANKLE JOINT

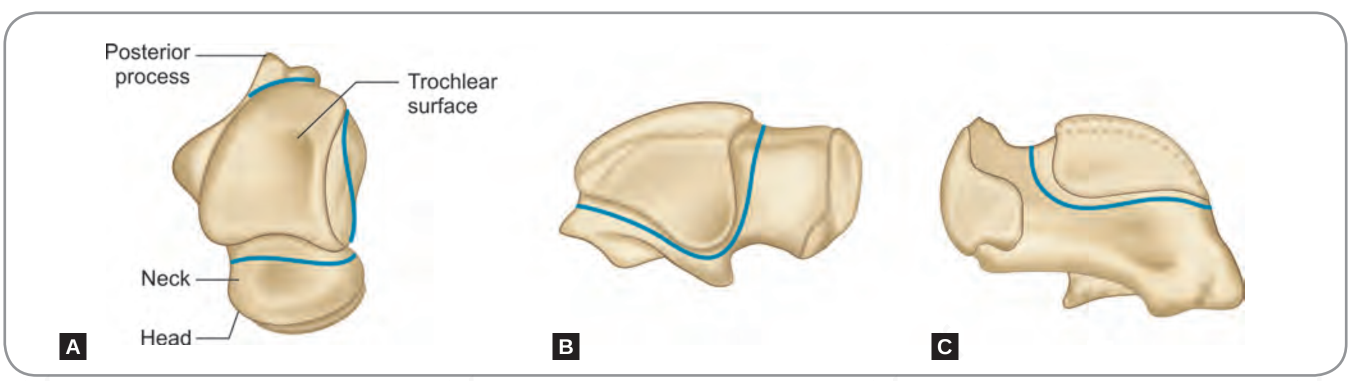
The ***ankle joint*** (or the ***talocrural joint*** or the ***hock joint***) is unique in that it plays a role in both stability and mobility of the lower extremity. It is placed and adapted in such a way that plantigrade standing and walking are possible. It is a synovial joint of the hinge variety. It is formed between the lower ends of the leg bones on one hand and the upper part of the talus, on the other. It is a compound joint, since more than two articular bony areas are involved.

Articular Surfaces

The articular surfaces of the ankle joint are complicated The distal ends of tibia and fibula along with a part of the transverse tibiofibular ligament form the proximal articular mortise (or socket). Fitting into this mortise as a pulley is the superior articular facet of the talus; the medial and lateral articular facets of the talus articulate respectively with the lateral surface of the medial malleolus and the medial surface of the lateral malleolus which form part of the mortise (Figs 29 16A to c).

The ***proximal articular surfaces*** (proximal articular mortise) are formed by the distal articular facet of the tibia, the lateral surface of the medial malleolus, the medial surface of the lateral malleolus and the anterior surface of the transverse tibiofibular ligament. The distal articular facet of the tibia is present on the inferior surface of the bone; it is partly concave and partly convex (saddle shaped); it is prolonged downward on the posterior aspect, thus causing a flange. The lateral surface of the medial malleolus has a comma shaped articular facet. The articular facets on the inferior surface and the medial malleolus are continuous with each other. Apart from the tibia and fibula, the transverse tibiofibular ligament (otherwise called the ***inferior transverse tibiofibular ligament***) also participates in the articulation. This ligament passes transversely from the posterior edge of the inferior surface of tibia to the malleolar fossa of the fibula. It deepens the mortise and comes in contact with an area between the posterior part of the trochlear and lateral articular surfaces of the talus.

The ***distal articular surfaces*** (the talar trochlea) are seen on the superior, medial and lateral surfaces of the talus. The superior or trochlear surface is convex from front to back. It is slightly concave from side to side, resembles a pulley and hence the name trochlear surface. This surface is widest in its anterior part and becomes narrower posteriorly. It comes in contact with the reciprocally shaped surface on the inferior surface of the tibia A small portion on the posterolateral aspect of this surface comes in contact with the anterior surface of the transverse tibiofibular ligament. The medial side of the talus bears a comma-shaped articular surface that is wide anteriorly and tapers off at its posterior end. The medial surface articulates with the reciprocal articular facet on the lateral surface of the medial malleolus of the tibia. The lateral surface of the talus has a large triangular surface the apex of the triangle being directed downwards; its



Figs 29.16A to C: Right talus showing attachments of the capsule of the ankle joint **A.** Superior aspect **B.** Lateral aspect **C.** Medial aspect

base is separated from the trochlear surface by a ridge. The surface is concave from above downwards. It articulates with the articular facet on the medial surface of the lateral malleolus of the fibula. The three articular facets of the talus together are often referred to as the ***trochlea tali*** (Latin.trochlea=pulley).

Articular Capsule

The fibrous capsule of the ankle joint is attached just beyond the margins of the articular surfaces. A small part of the neck of the talus is included within the joint cavity. The capsule is weak anteriorly and posteriorly, but on the medial and lateral side it is reinforced by strong ligaments.

Ligaments

It is necessary that the fibrous capsule of the ankle is thin to allow movements of the plantigrade foot on the distal end of the leg. It is also equally essential that the ankle joint is adequately strengthened to prevent dislocations to which, it is easily prone. On the medial and lateral sides, the joint capsule is reinforced by strong medial and lateral collateral ligaments (Fig. 29.17).

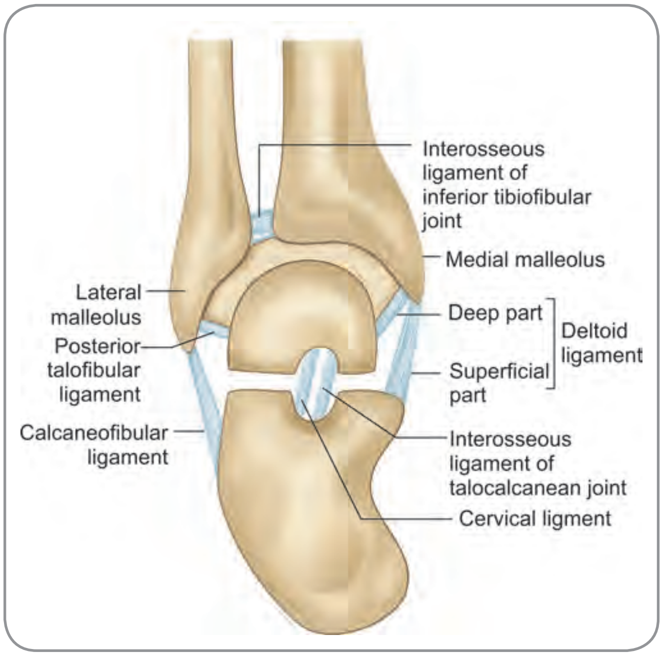
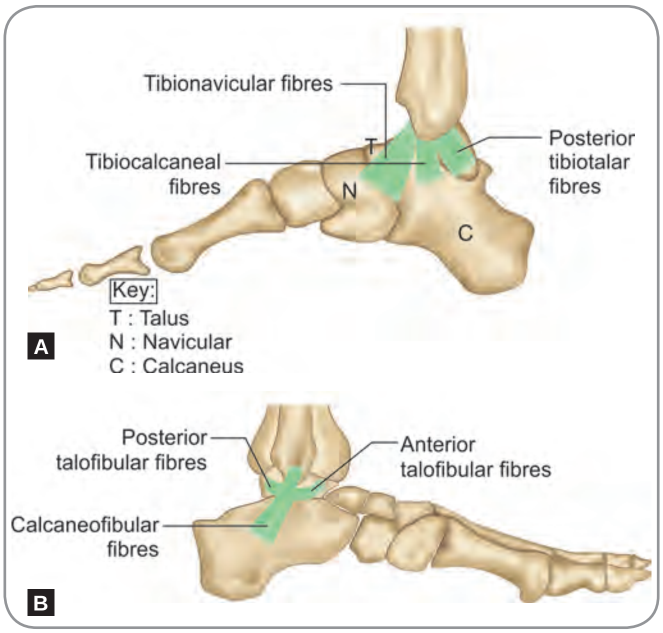


Fig. 29.17: Important ligaments of ankle joint

Medial Collateral Ligament

It is popularly known as the ***deltoid ligament*** (Fig. 29.18A) (owing to its triangular shape, resembling the Greek letter delta). It is attached proximally (or above) to the apical portion of the medial malleolus and is triangular in shape. Its anterior fibres pass downwards and forwards to the tuberosity of the navicular bone and constitute the ***tibionavicular ligament***. The middle fibres are attached, below, to the sustentaculum tali of the calcaneus and form the ***tibiocalcanean ligament***. Between the anterior and middle bands, the intervening fibres of the deltoid ligament blend with the plantar calcaneonavicular (spring) ligament. The posterior fibres pass backwards to be attached to the posterior part of the medial side of the talus. They form the ***posterior tibiotalar ligament***. Deeper fibres attached more anteriorly on the talus form the ***anterior tibiotalar ligament***. The medial ligament stabilizes the joint during eversion and prevents dislocation of the joint.



Figs 29.18A and B: Collateral ligaments of the ankle joint **A.** Deltoid ligament **B.** Lateral ligament

Lateral Collateral Ligament

Otherwise called the ***lateral ligament*** (Fig. 29.18B) of the ankle, it consists of three completely separate parts—the first part is the.

- ***Anterior talofibular ligament*** which is attached proximally to the anterior margin of the lateral malleolus. Its fibres pass forwards and medially to reach the talus anterior to its lateral articular surface
- ***Posterior talofibular ligament*** which is attached proximally to the malleolar fossa (behind the articular surface). Its fibres pass transversely to the lateral tubercle of the posterior process of the talus.
- ***Calcaneofibular ligament*** which is attached proximally to the apex of the lateral malleolus. Its fibres run downwards and backwards to the lateral surface of the calcaneus. The lateral ligament is a compound structure.

Role of Ligaments of the Ankle Joint

Four ***ligaments*** (two parts of the medial ligament namely—(1) the tibiocalcanean and (2) the posterior

tibiotalar ligaments and two parts of the lateral ligament, namely—(1) the posterior talofibular and (2) the calcaneofibular ligaments) pass backwards from their proximal attachments to reach their distal attachments. They resist the forward displacement of the leg which functionally is equivalent to backward displacement of the foot. While passing backwards, the four ligaments also span the talus and help hold it in position. The anterior talofibular ligament is the weakest of the ligaments of the ankle.

Synovial Membrane

The synovial membrane of the ankle joint is loose and lines the joint cavity. Since part of the neck of talus is intracapsular, it is also covered by synovial membrane. The synovial cavity also extends upwards between the tibia and the fibula as far as the interosseous tibiofibular ligament.

Dissection

Clean up the remnants of the retinacula around the ankle. Identify the various muscles and tendons. Cut and reflect them as necessary. Define the joint capsule. Identify the deltoid and lateral collateral ligaments and their constituent parts. Define and study them.

Relations

Anteriorly (from medial to lateral): Tibialis anterior, extensor hallucis longus, anterior tibial vessels, deep peroneal nerve, extensor digitorum longus and peroneus tertius

Posteriorly: (from medial to lateral): Tibialis posterior, Flexor digitorum longus, posterior tibial vessels, tibial nerve and flexor hallucis longus.

Medially: The deltoid ligament, tibialis posterior and flexor digitorum longus.

Laterally: The calcaneofibular part of the lateral ligament, the peroneus longus and the peroneus brevis.

Blood Supply

The malleolar branches of the anterior and posterior tibial and the peroneal arteries supply the akle joint.

Nerve Supply

Articular branches from the tibial and deep peroneal nerves supply the joint.

Movements

The primary movements which take place at the ankle joint are those of plantarflexion and dorsiflexion of foot, around a transverse axis passing through the talus.

Plantarflexion provides the propulsive force for walking, running and jumping. It is for this reason that the main muscles responsible for it (gastrocnemius and soleus) and their tendon (tendocalcaneus) are so powerful. During walking, plantarflexion is accompanied by flexion at the knee joint (both movements lifting the limb off the ground) and the gastrocnemius contributes to both these movements.

Though there are five muscles—[(1) Tibialis posterior and (2) Flexor digitorum longus behind the medial malleolus, (3) Flexor hallucis longus midway between the malleoli, (4) Peroneus longus and (5) Peroneus brevis behind the lateral malleolus] passing behind the ankle, all of them are too close to the transverse axis of the ankle joint such that their action on the joint is minimal. The major plantarflexor thus are the gastrocnemius and soleus. If the tendocalcaneus is damaged or cut, ability to dorsiflex is lost.

During plantarflexion, the narrower portion of the talar trochlea fits loosely into the malleolar mortise. It is then possible for the trochlea to ***wobble*** a little and so, small amounts of abduction, adduction, inversion and eversion of the foot occur (Table 29.3).

Factors of Instability and Stability in the Ankle Joint

The weight of the body is transmitted through the tibia to the talus. From the talus, it is then transmitted both anteriorly and posteriorly. Since the ankle occupies a location which is very close to the ground in the erect posture, force of gravity also acts on the joint. These two factors predispose the ankle to instability. Attachments of muscles and ligaments influence this predisposition.

Table 29.3: Movements of the ankle joint

Movements	Muscles producing movements	Factors limiting movements
Plantarflexion	Principal muscle: Gastrocnemius, soleus (mainly) Accessory muscles: plantaris, tibialis posterior, flexor digitorum longus and flexor hallucis longus	Very minimal resistance is given by the ligaments; in trained dancers (especially ballet toe dancers), the dorsum of foot and the anterior surface of leg can be brought in the same line
Dorsiflexion	Principal muscle: Tibialis anterior Accessory muscles: Extensor hallucis longus, extensor digitorum longus, peroneus tertius	Passive resistance in triceps surae and tension in medial and lateral collateral ligaments

- All tendons crossing the ankle except the tendocalcaneus are attached to the anterior part of he foot. When the muscles of these tendons contract, there is a tendency for the leg to be dislocated forward at the ankle.
- When we rise from the sitting position, 'we rise on our toes'; the toes and the forefoot are pressed to the ground and the heel lifted up; force of gravity at this point tends to displace the leg forward.
- Plantarflexion causes the narrower portion of the talar trochlea to engage with the malleolar mortise. This causes a loose fit of the articular areas and allows the talus to move sideways. Since the body weight falls in front of the joint, the leg tends to get displaced forward.
- Of the four factors which decide the stability of a joint, two factors (gravity and muscular attachments) are disadvantageous to the ankle and tend to cause forward displacement of the leg, which in essence is equivalent to backward displacement of the foot.
- The other two factors (bones and ligaments) compensate for this and tend to enhance the stability of the joint. The bony parts are so placed that the malleoli tend to grasp the sides of the talus. The ligaments pass not only downward; but also backwards so as to retain the leg in position.

Added Information

- The significance of the ankle joint is in its effective role in ***walking***. The gastrocnemius and soleus cause Plantarflexion and raise the heel from the ground. Once this act of propulsion (heel raised up and the forefoot and toes pressing on the ground) is completed, the limb has to advance. Advancing is caused by the dorsiflexors which raise the foot off the ground (since the heel is already raised, dorsiflexion raises the entire leg and clears it from the ground). Alternate plantarflexion and dorsiflexion (hinge action of the ankle) therefore cause the walking movements.
- The hinge action of the ankle is facilitated further by the position of the muscles. There are no muscles on the sides of the ankle and the malleoli and the lower shafts of both the leg bones are subcutaneous. All the muscles are grouped in the anterior and posterior aspects thus helping the action of the hinge.
- The most unstable position of the ankle is plantarflexion. It is also the most unstable position of the individual during walking.
- While walking on uneven ground, there is a natural tendency to walk on the heels or ***dig the heels*** into the ground; this gives the foot a position of stability because in this position the talar trochlea is tightly grasped by the malleolar mortise.
- The obliquity of the various ligaments of this joint and the obliquity of the fibular articular area give suppleness to the joint. The mortise is not rigid and permits sideward and upward movements.
- The medial collateral ligament is so strong that over-eversion of the foot or violent strains to the ligament cause avulsion of the medial malleolus than tearing of the ligament.
- The tibiofibular ligaments are also obliquely placed. They allow the fibula to move upwards and laterally When the fibula moves so, the mortise is widened and the broader aspect of talus engages in it. The joint is thus rendered stable.

contd...

Added Information *contd...*

- The superior articular facet of talus is concave transversely. Owing to this concavity, weight transmitted through the talus is distributed in two components. The lateral component is larger and is passed on to the calcaneus. The medial component is smaller and is passed on to the sustentaculum tali and other tarsal bones to reach the ball of toes.

Clinical Correlation

- Ankle is the most frequently injured major joint of the body.
- Ankle sprains (where the ligaments sustain tears) are common.
- Inversion injury is a type of sprain that occurs when the foot is forcibly inverted while walking on an uneven surface. The fibres of the lateral ligament are torn. Competitive jumping and group sports may cause sprains of the lateral ligament. Since it is a weaker ligament and resists inversion, it is injured more.
- In most of the ankle sprains, the anterior talofibular ligament is either partially or completely torn resulting in instability of the joint.
- Shearing injuries to the joint cause associated fibular fractures. Part of the lateral malleolus inferior to the ankle may be pulled off resulting in avulsion fractures.
- Pott ***fracture-dislocation*** of the ankle is a complicated condition resulting from forcible eversion of the foot. The strong medial ligament is pulled, in turn pulling off the medial malleolus. The talus moves laterally, shears the lataral malleolus and breaks the fibula. The tibia moves anteriorly and its distal portion is also sheared off. The distal end of tibia is spoken of as an additional malleolus and the fracture is described as the ***trimalleolar fracture.***
- Because of the mortise arrangement, dislocations of the ankle joint are invariably associated with fractures of malleoli or separation of the lower ends of the tibia and fibula by rupture of the interosseous tibiofibular ligament.

INTERTARSAL JOINTS

These are joints between the tarsal bones. Of these, the joints involved in inversion-eversion movements are important. They are the large intertarsal joints consisting of the subtalar joints and the transverse tarsal joints.

Subtalar Joints

Two subtalar joints are described—(1) the anatomical subtalar joint and (2) the clinical subtalar joint.

Anatomical Subtalar Joint

It is a joint where the talus rests on the calcaneus. It is also called the ***talocalcaneal joint or the posterior***

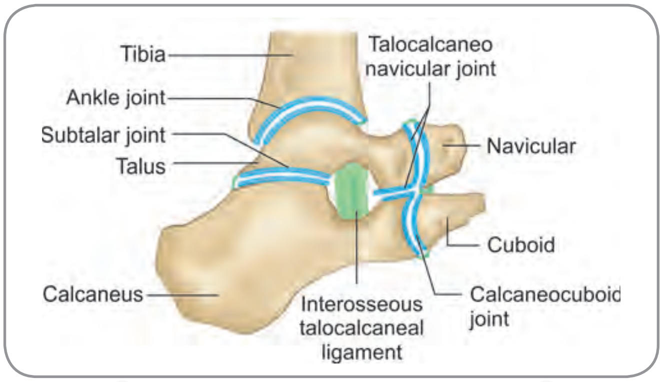


Fig. 29 19: Schematic vertical section along the long axis of the talus to show the various joints formed by it

talocalcaneal joint. It consists of a ***single synovial joint*** of the plane variety, between the concave posterior articular facet on the inferior surface of talus and the convex posterior articular facet on the superior surface of calcaneus. The ***articular capsule***, which is attached close to the articular margins all around, is thin and weak but is reinforced by the medial, lateral, posterior and interosseous talocalcaneal ligaments. The ***medial***, ***lateral*** and ***posterior talocalcaneal ligaments*** are thickenings of the corresponding portions of the capsule. The anterior part of the capsule which is extremely thin is attached to the roof and floor of the sinus tarsi (it should be remembered that the sinus tarsi runs obliquely forwards and laterally in front of the articular facets of this joint). Within the sinus tarsi (tarsal sinus) is present the ***interosseous talocalcaneal ligament***. It is a strong ligament that separates the posteriorly placed anatomical subtalar joint from the anteriorly placed talocalcaneonavicular joint. Another ligament adding strength to this joint is the ***ligamentum cervicis*** or the ***cervical ligament*** extending from the superior aspect of calcaneus to the inferolateral area of the neck of talus. It is lateral to the sinus tarsi and the interosseous ligament (Fig. 29.19).

As much as the anterior part of the capsule of the subtalar joint is attached to the sinus tarsi, the posterior part of the capsule of the talocalcaneonavicular joint is also attached to the sinus tarsi. In fact both of them blend with the posterior and anterior aspects of the interosseous talocalcaneal ligament respectively.

Clinical Subtalar Joint

The term ***subtalar joint*** is applied to the ***functional compound joint*** consisting of the anatomical subtalar joint and the talocalcaneal part of the talocalcaneonavicular joint. The two separate entities of the clinical compound joint straddle the interosseous talocalcaneal ligament.

The anatomical definition is correct from the structural standpoint because the two joints have their own separate joint cavities and joint capsules. The clinical definition is correct from the functional standpoint because the two together function as a single unit and cannot function separately.

Transverse Tarsal Joints

These are two separate joints which lie along the same transverse plane and align with each other. They are—(1) the ***talocalcaneonavicular joint*** and (2) the ***calcaneocuboid joint***.

Talocalcaneonavicular Joint

It is a ***compound synovial joint*** of the ball and socket variety, where a large convex facet present on the head and inferior aspect of the neck of talus articulates with a deep socket formed by bones and ligaments. The anterior part of the socket is formed by the concave articular facet on the posterior surface of navicular bone. The posterior part of the socket is formed by the articular facet present on the superior surface of sustentaculum tali and another adjacent facet on the superior surface of calcaneus, anterolateral to the sustentaculum. Between the anterior and posterior parts of the socket is an interval which is occupied by ligaments. The medial part of the interval is bridged by ***plantar calcaneonavicular ligament*** and the lateral part by the ***calcaneonavicular portion of the bifurcate ligament***. Thus the socket is osseoligamentous (Fig. 29.20) and the talus articulates with the calcaneus and navicular bones and also with the superior aspects of the ligaments. Due to the extensive osseofibrous arrangement of its component parts, the joint has a capsule which is discernible only in the posterior and dorsal aspects. The posterior part of the fibrous capsule merges with (as already mentioned) the anterior aspect of the interosseous

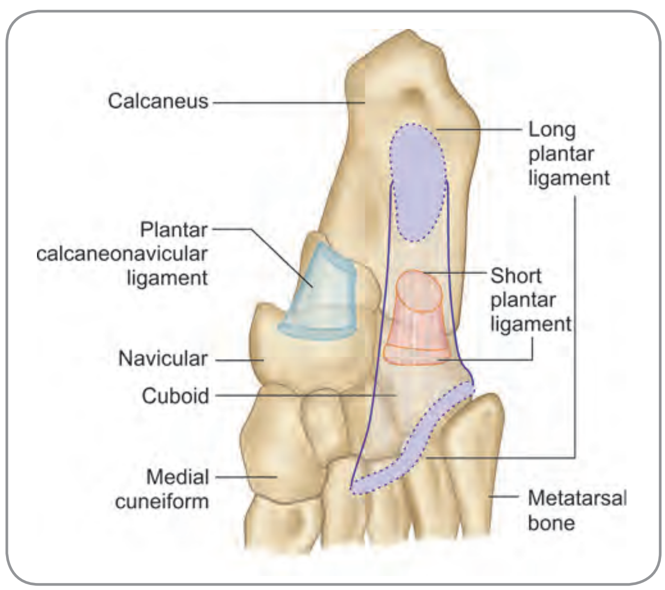


Fig. 29.20: Posterior part of right foot (plantar aspect) to show attachments of some ligaments

talocalcaneal ligament. The dorsal aspect of the capsule is reinforced by the talonavicular ligament. The synovial membrane lines all the non-articular areas and the cavity does not communicate with any other joint cavity. The talus and the calcaneus do not articulate directly in this joint and the spring and the bifurcate ligaments connect the two bones.

Calcaneocuboid Joint

This ***synovial joint*** forms the highest point in the lateral longitudinal arch of the foot. The articular surfaces are the reciprocally concavo-convex quadrilateral surfaces on the anterior surface of the calcaneus and the posterior surface of the cuboid. The fibrous capsule surrounds the joint and is reinforced by special ligaments. Closely applied to the dorsomedial aspect of the capsule is the ***calcaneocuboid part of the bifurcate ligament*** On the plantar aspect of the joint are two important ligaments. The deeper of the two is the ***short plantar ligament*** and the more superficial and longer one is the ***long plantar ligament***. The synovial membrane lines the capsule and the cavity does not communicate with any other joint cavity.

The talocalcaneonavicular and the calcaneocuboid joints do not communicate with each other but together extend across the tarsus in an irregular transverse plane. This plane lies between the talus and the calcaneus posteriorly and the navicular and the cuboid anteriorly. The plane is considered a functional joint between the posterior and the anterior set of bones and is termed the transverse tarsal joint. The forefoot and midfoot together rotate as a single unit on the hindfoot at this joint around a longitudinal axis that runs anteroposteriorly. This rotation augments inversion-eversion movements which occur at the subtalar articulation.

Movements at Subtalar and Transverse Tarsal Joints

The movements which occur at the subtalar and transverse tarsal joints, in toto, produce inversion and eversion. Both inversion and eversion are composite movements.

When the great toe is raised and the dorsum faces laterally, it is called ***supination*** (of foot); and when the little toe is raised and the sole faces laterally, it is ***pronation*** (of foot). The axis of this set of movements is anteroposterior along the long axis of the foot. Supination is lateral rotation of the foot and pronation is medial rotation.

When the foot is moved medially in an arc of a circle, it is adduction (toes pointing inwards); when it is moved laterally in a similar arc, it is abduction (toes pointing outwards) The axis of this set of movements is the vertical axis through the leg.

When supination and adduction are combined, the sole is turned to face the opposite side with the medial border of the foot raised, the lateral border depressed and the foot adducted. This combination of movements is inversion. When pronation and abduction are combined, the sole is turned to face laterally with the lateral border raised, the medial border depressed and the foot abducted. This combination of movements is eversion.

Inversion is usually associated with plantarflexion and eversion with dorsiflexion. Inversion and eversion occur predominantly at the subtalar and the transverse talar joints. The joints have a common axis of movement that runs upwards, forwards and medially through the sinus tarsi.

When the foot is on the ground and bearing weight, inversion-eversion movements are restricted. Only lateral rotation (supination of forefoot where the great toe is raised and dorsum of forefoot turns laterally) and medial rotation (pronation of forefoot where the little toe is raised and dorsum of forefoot turns medially) can occur. Such movements can be seen while standing on an uneven or sloping ground.

Muscles Producing Movements

Inversion is produced by tibialis anterior and tibialis posterior. Both have attachements to the medial border of the foot, the tibialis anterior to the base of the first metatarsal bone and the first cuneiform and the tibialis posterior to the navicular. Contraction of these muscles thereby causes raising of the medial border; they also help in maintenance of the medial longitudinal arch (Fig. 29.21).

Eversion is produced by peroneus longus, peroneus brevis and peroneus tertius. The peroneus brevis and tertius are attached to the lateral border of the foot (Fig. 29.22), brevis to the base of the fifth metatarsal bone (Fig. 29.23) and the tertius either to the base or the dorsal aspect of the shaft of the same bone. Their contraction thus raises the lateral border of the foot. Peroneus longus passes under the lateral border to cross the sole. Its contraction also, acting as a hook, raises the lateral border. These three muscles, in addition to being evertors, help in the maintenance of the lateral longitudinal arch (Fig. 29.24).

The tendinous sling action for the medial longitudinal arch is provided by the tibialis posterior and that for the lateral longitudinal arch by the peroneus longus (Fig. 29.25).

The muscles of inversion and of eversion are attached in front of the transverse tarsal plane.

Clinical Correlation

Inversion-eversion movements are extremely complex. Until now, it had not been possible to bring about these movements in artificial limbs. People with such contraptures find it difficult to walk on uneven surfaces.

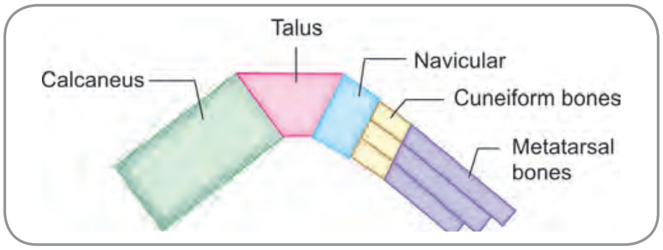


Fig. 29.21: Scheme to show constitution of the medial longitudinal arch of the foot

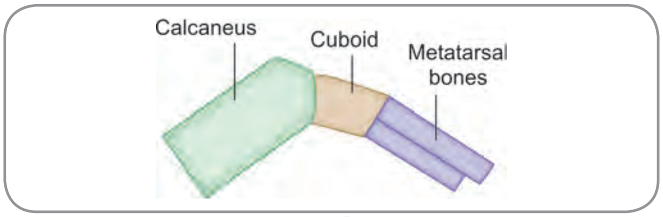


Fig. 29.22: Scheme to show constitution of the lateral longitudinal arch of the foot

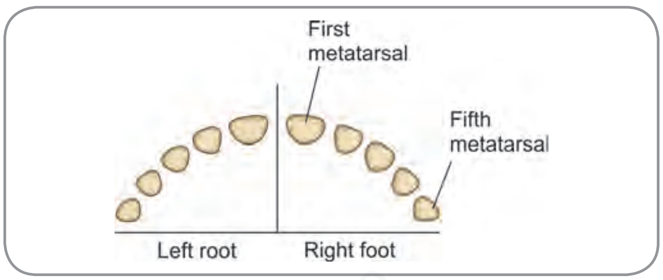


Fig. 29.23: Scheme to show transverse arch formed by the two feet. Note that each foot forms half of the arch

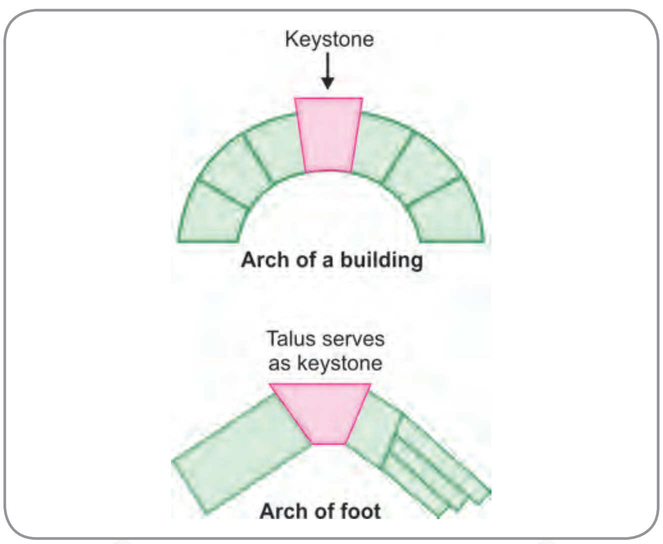


Fig. 29.24: Scheme to show how the talus serves as a key-stone that helps to maintain longitudinal arches of the foot

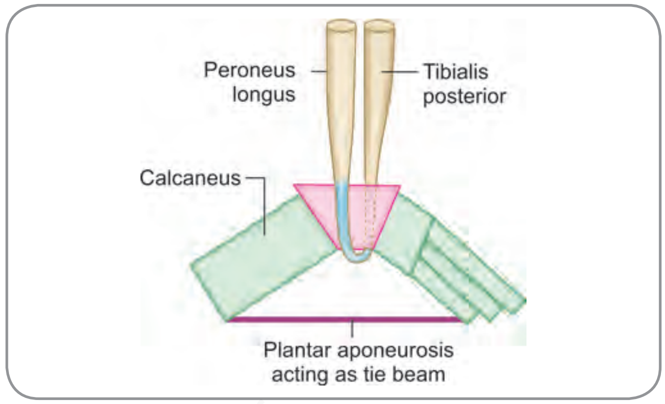


Fig. 29.25: Scheme to show the tie-beam action of the plantar aponeurosis and the tendinous sling action provided by the muscles

Small Intertarsal Joints

These include all those intertarsal joints lying anterior to the transverse tarsal joints. They are the ***cuneonavicular, intercuneiform*** and the ***cuneocuboid joints***.

- ***Cuneonavicular joint*:** It is a plane synovial joint between the convex articular surface of the anterior aspect of the head of navicular and the concavity produced by the posterior aspects of the three cuneiform bones. A fibrous capsule surrounds the joint but the cavity may be communicating with the cuneocuboid joint through a deficiency in the capsule. Dorsal and plantar cuneonavicular ligaments which pass from the navicular bone to each of the cuneiforms on the respective aspects reinforce the capsule. Tibialis posterior tendon slips merge with the plantar ligaments.
- ***Intercuneiform joints*:** Weak dorsal and stronger plantar and interosseous ligaments bind the three cuneiforms together. There are no joint cavities between these ligaments but the cuneonavicular joint cavity gives out small recesses between the cuneiform bones. The interosseous cuneiform ligaments form anterior boundaries to these recesses.
- ***Cuneocuboid joint*:** It is a plane synovial joint between the round facet on the lateral surface of the lateral cuneiform bone and the round facet on the medial surface of the cuboid bone. Dorsal and plantar cuneocuboid ligaments connect the bones. An interosseous cuneocuboid ligament connects the anterior aspects of the contiguous sides of the two bones. A small joint cavity lies posterior to the interosseous ligament.

Side to Side and End to End Joints

A close study of the small intertarsal joints will indicate that wherever the anterior and posterior surfaces of two bones

came into contact, the surfaces are covered with articular cartilages and the joints have cavit es. There are no interosseous ligaments in these aspects. However, strong plantar ligaments and weak dorsal ligaments connect the bones. A few collateral ligaments are also present. These are the end to end joints and participate in the longitudinal arches of the foot. Since the longitudinal arches are longer, it is necessary to have small segments within the length of the arch. The side to side joints are those which participate in the transverse arch of the foot. The sides of adjacent bones articulate with each other but are connected by strong plantar and interosseous ligaments. Joint cavities, when present are small.

Nerve Supply to the Tarsal Joints

All the tarsal joints are supplied by branches of deep peroneal nerve on the dorsal aspect and by branches of medial and lateral plantar nerves on the plantar aspect.

Ligaments of the Region

- ***Plantar calcaneonavicular or spring ligament:*** It passes from the anterior and medial margins of the sustentaculum tali of the calcaneus to the plantar surface of the navicular bone. Its medial margin is joined by fibres of the deltoid ligament of the ankle. It is in contact above with the head of the talus and its upper surface forms part of the articular surface of the talocalcaneonavicular joint The tibialis posterior tendon turns into the sole under this ligament and forms a sling for it and the head of talus. Weight of the body tends to drive the head of talus down between the calcaneus and navicular. The plantar calcaneonavicular ligament along with the support it receives from the sling action of tibialis posterior, resists this tendency By this action, the ligament also helps in the maintenance of medial longitudinal arch thus justifying its specific appellation—the spring ligament.
- ***Bifurcate ligament*:** It is Y-shaped. The stem of the Y is attached posteriorly to the anterior part of the upper surface of the calcaneus. Anteriorly, it splits into two bands—one passing to the dorsal aspect of the cuboid bone and another to the dorsal aspect of the navicular bone.
- ***Long plantar ligament*:** It is ligament between the calcaneus and the cuboid bones. It is attached posteriorly to the plantar surface of the calcaneus (to a rounded ridge in front of the medial and lateral tubercles); and anteriorly to a ridge on the plantar surface of the cuboid bone, distal to the groove for the peroneus longus. As it is attached distal to the groove, it converts the groove into a tunnel. Some fibres of the ligament are prolonged over the peroneus longus tendon into the bases of the 2nd, 3rd and 4th metatarsal bones. The ligament therefore stretches under the whole length of the lateral longitudinal arch. As this arch is of lesser height than the medial one, a long band stretching from pillar to pillar can help maintain the arch than shorter ties between smaller segments.
- ***Short plantar ligament* (or *plantar calcaneocuboid ligament*):** It is also a ligament between the calcaneus and the cuboid. It passes from the anterior tubercle of the calcaneus to the cuboid bone proximal to the groove for the peroneus longus.
- ***Interosseous talocalcaneal ligament*:** It is a ligament found in the sinus tarsi. It lies deep between the talus and the calcaneus and passes from the sulcus tali to the sulcus calcanei joining the talus and calcaneus in the interval between the subtalar and talocalcaneo-navicular joints.
- ***Talonavicular ligament*:** It is a ligament on the dorsal aspect of the foot extending between neck of talus posteriorly and the dorsal aspect of navicular bone anteriorly. It blends medially with the tibionavicular component of the deltoid ligament.
- ***Cuboideonavicular ligaments*:** There are three of these ligaments, namely—(1) the dorsal, (2) the plantar and (3) the interosseous cuboideonavicular ligaments. The dorsal and the plantar ligaments extend between the adjacent parts of the corresponding surfaces The interosseous ligament extends between the contiguous sides of the two bones. These ligaments facilitate the midfoot-hindfoot rotation at the transverse tarsal plane
- ***Cuneonavicular ligaments:*** There are two sets of them—(1) the dorsal and (2) the plantar cuneonavicular ligaments. Each set has three ligaments running from the navicular to the three cuneiforms on the respective surfaces.
- ***Intercuneiform ligaments:*** Dorsal intercuneiform ligaments run between the cuneiforms on the dorsal surface, the plantar ligaments on the plantar surface and the interosseous ligaments on their contiguous surfaces.
- ***Cuneocuboid ligaments:*** Dorsal cuneocuboid ligament connects the two bones on the dorsal surface, plantar ligaments on the plantar surface and the interosseous ligament on their contiguous surfaces.

OTHER JOINTS OF FOOT

Tarsometatarsal Joints

The three cuneiform bones and the cuboid articulate with the five metatarsal bones. The first metatarsal articulates with the medial cuneiform, the second with all three cuneiforms as in a socket, the third with the lateral

cuneiform, the fourth with the lateral cuneiform and the cuboid and the fifth with the cuboid bone. All these joints are synovial of the plane variety Dorsal and plantar tarsometatarsal ligaments connect the corresponding bones. Two interosseous ligaments are present; one connects the lateral aspect of the medial cuneiform to the medial aspect of the second metatarsal; the other connects the lateral aspect of the lateral cuneiform to the medial aspect of the fourth metatarsal. Thus, three joint cavities are formed. The medial cavity is between the first metatarsal and the medial cuneiform; the intermediate cavity is between the second and third metatarsals and the intermediate and lateral cuneiforms; the lateral cavity is between the fourth and fifth metatarsals and the cuboid.

Intermetatarsal Joints

The bases of the first and the second metatarsals are connected by fibrous tissue. The bases of the lateral four metatarsals articulate to form four small synovial cavities. Dorsal, plantar and interosseous intermetatarsal ligaments are present.

Movements at the Tarsometatarsal and Intermetatarsal Joints

Slight gliding movements occur at these joints and help in ***inversion-eversion movements*** and in adaptation of the foot to uneven surfaces.

Both the tarsometatarsal and intermetatarsal joints are supplied by deep peroneal and medial and lateral plantar nerves.

Metatarsophalangeal Joints

Each metatarsal head articulates with the cup shaped posterior ends of the proximal phalanges of the corresponding toe, forming a condyloid synovial joint. A small fibrous capsule is present and is reinforced by strong plantar and collateral ligaments. The dorsal aspect of the capsule is replaced by dorsal digital expansion The plantar ligaments of all the five joints are interconnected by the deep transverse metatarsal ligament. Flexion-extension and abduction-adduction occur. In flexion, the toes are drawn together and in extension they spread apart and also move a little laterally. Extension of the phalanges beyond the line of the metatarsals is possible. Abduction-adduction are centred on an axis passing through the second toe.

Interphalangeal Joints

Each proximal bone presents a double convexity which fits into the double concavity of the distal bone. These synovial hinge joints have a capsule and collateral and plantar ligaments. The dorsal aspect of the capsule is replaced by dorsal digital expansion. Flexion and extension movements occur.

The metatarsophalangeal and the interphalangeal joints are supplied by dorsal and plantar digital nerves.

ARCHES OF FOOT

The bones of the foot are so arranged that they form a series of arches. There are two longitudinal arches—medial and lateral; and a transverse arch.

Components and Pillars of the Arches

- The ***medial longitudinal arch*** is formed (from posterior to anterior side) by:
  - The calcaneus.
  - The talus.
  - The navicular
  - The medial, intermediate and lateral cuneiform bones.
  - The medial three metatarsal bones.

  The arch rests posteriorly on the tubercles of the calcaneus, and anteriorly on the heads of the metatarsals. The summit of the arch is formed by the talus (medial part of the superior surface).The posterior formed by the calcaneus is s steep slope and the anterior pillar formed by navicular, cuneiforms, the bases of the medial three matatarsals and ending in the heads of the same metatarsals is a gradual slope.
- The ***lateral longitudinal arch*** is formed by:
  - The calcaneus.
  - The cuboid.
  - The lateral two metatarsal bones.

  The arch rests posteriorly on the calcaneus and anteriorly on the heads of the lateral two metatarsals. The summit is at the calcaneocuboid joint. The posterior pillar formed by the lateral part of the calcaneus is short and has a sharper decline than that of the medial arch. The anterior pillar formed by the cuboid, bases of the lateral two metatarsals ends in the heads of the same metatarsals and has a far shorter gradient.

  It can well be noted that calcaneus is common to both arches and forms the common posterior pillar. The medial longitudinal arch is higher. The lateral longitudinal arch is much flatter than the medial arch and rests on the ground while standing
- The ***transverse arch*** is best marked in the middle of the foot It is formed by the cuneiforms, cuboid and the bases of the metatarsal bones. At the level of the metatarsal shafts and the metatarsal heads, the arch is flatter; however the formation of the arch is shown by the fact that the heads of second to fourth metatarsals bear less weight than the heads of the first and the fifth metatarsals. The medial and lateral longitudinal arches form the pillars of the transverse arch. Individually, each foot has only half an arch and the complete transverse arch is formed when the feet are placed together. As a result of the transverse arch, the medial border of the foot remains off the ground in its middle part.

Necessity and Significance of the Arches

The human foot is specialized for the support of the body in the erect posture and for propulsion during movement. To achieve its goal, the foot should be able to adapt itself to varied positions of the ground and be able to absorb mechanical shock and stress. The specialization to cater for all these needs is the presence of the arches of foot. The arches are all convex superiorly; they get flattened a little while standing and during locomotion and resume their original shape and curvature when pressure (body weight) on them is relaxed.

Role of Talus and Intertarsal Joints in Maintenance of the Arches

Body weight is transmitted from the leg bones to the foot through the talus. It is already noted that the clinical subtalar joint is a single functional unit consisting of the anatomical subtalar joint and (a part of) the talocalcaneonavicular joint. For purposes of weight transmission, both the components play crucial roles. Each of them is concerned with transfer of weight to one of the longitudinal arches. The posterior component or the anatomical subtalar joint is associated with the lateral longitudinal arch and transfers weight to the latter. At the anterior component or the talocalcaneonavicular joint, weight is transferred to the medial longitudinal arch. At both joints, talus rests on the calcaneus and enjoys its most deserved stability.

Functions of the Arches

The arches and their component joints provide the foot with a spring mechanism When weight or pressure is applied, the arches yield a little; when the same is removed, they recoil. The medial longitudinal arch, by being higher than its lateral counterpart, gives more resilience to that part of the foot and facilitates propulsive action. The lateral longitudinal arch is flatter and helps the lateral part in being the actual static support of the body. As a result of the presence of the arches, body weight is transmitted to the ground only through the tuberosity of the calcaneus and the heads of the first and fifth metatarsal bones. The lateral longitudinal arch bears the body weight (in the most economical way with no muscle acting then) during standing and the medial arch during locomotion.

Factors Maintaining the Arches

These can be classified into three groups, namely—(1) the bony factors, (2) the ligamentous factors and (3) the muscular factors.

- ***Bony factors:*** The shapes and sizes, location and postion of the various bones of the foot along with the configuration of the articular surfaces play an important role. The talus contributes significantly in the maintainence of the medial longitudinal arch by acting as its keystone. The positioning of the talus at a level higher than the rest of the tarsal bones is important. The various joints and their articular surfaces are so arranged that there is a natural inclination from the talus to the heads of the metatarsals. The shapes of the anterior tarsal bones, namely the navicular, cuneiforms and the cuboid provide for the formation of smaller arcs within the arches so that resilience is at its best.
- ***Ligamentous factors:*** Flattening of the arches is prevented by ligaments; the role of ligaments in providing the most required reinforcements cannot be undermined.
  - The talus is the highest point in the medial arch; body weight falls on it and hence maximum strain is felt at the head of talus and the talocalcaneonavicular joint. The calcaneocuboid joint is the highest point in the lateral arch. Body weight falls at the subtalar joint and the maximum strain is felt at the calcaneocuboid joint. It is therefore necessary that both the talocalcaneonavicular and the calcaneocuboid joints are reinforced on their inferior aspects. The spring ligament for the talocalcaneonavicular joint and the long and the short plantar ligaments for the calcaneocuboid joint provide such reinforcements.
  - The plantar aponeurosis plays an important role by connecting the anterior and posterior ends of the longitudinal arches like a ***tie-beam***.
  - The other ligaments of the intertarsal joints including the short intertarsal, bifurcate and the interosseous talocalcanean ligaments, the ligaments of the distal tibiofibular syndesmosis including the transverse tibiofibular ligament, the ligaments of the other joints of the foot including the deep transverse metatarsal ligament provide additional support to the arch mechanism.
- ***Muscular factors:*** During rapid changes of position and during movements including propulsion, the ligaments appear to be giving maximal support to the arches while the muscles are mere sideplayers. However, the role of the muscles in protecting the ligaments from being stretched under constant strain and the additional crucial force provided at times of sudden contrac ions cannot be overemphasized.
  - The tendon of tibialis posterior passes as a sling under the spring ligament and the summit of the medial arch thus keeping the arch raised; the attachments of the same tendon to nearly all tarsal and metatarsal bones increases the general concavity of the sole whenever the muscle contracts; the sling action of this tendon also resists the tendency of talus to move inferiorly under pressure and body weight (Fig. 29.25).
  - The tendon of peroneus longus passing under the cuboid acts as a sling for the lateral arch. The same tendon, by virtue of its extension across the sole, also acts as a tie-beam between the pillars of the transverse arch (Fig. 29.25).

- The Tibialis anterior and the peroneus tertius pull upon the medial and the lateral borders of the foot from above thus causing elevation of the respective arches.
- The long flexor tendons act as tie-beams to the longitudinal arch. The Turner s slip is so contributed that it helps to pull the toes forming the anterior pillar of the medial arch.
- The muscles of the sole help to keep the components of the arches in position. They play an active role under conditions of normalcy in maintaining the arches, unlike the long muscles which play a crucial role under conditions of mechanical load and stress.

Clinical Correlation

- Flattening of the arches is seen in some individuals. It is called ***flat foot*** or ***pes planus.*** It causes difficulty in walking. The medial arch suffers the most; during long periods of standing, the ligaments are over stretched leading to further flattening and lateral deviation of the foot. The gait is clumsy; due to altered shape, the foot is prone to injuries. compression of the nerves may also occur resulting in pain and swelling.

contd…

Clinical Correlation *contd...*

- The reverse condition in which the arches are too marked is termed ***pes cavus***. It is associated with claw foot, where dorsiflexion of metatarsophalangeal joints and plantarflexion of interphalangeal joints occur
- In some chromosomal abnormalities, plantar convexity is seen. Such feet are called ***rocker bottom feet***. Trisomy 18 is associated with this condition.
- Abnormality or paralysis of interossei and sometimes lumbricals causes hammer toe deformity. Lateral four toes suffer. Hyperextension at metacarpophalangeal joints, hyperflexion at proximal interphalangeal joints and extension at distal interphalangeal joints are seen.
- Talipes deformities of the foot may also occur. In talipes equinovarus, the deformity and its outcome resemble the toes of the horse. Foot is plantarflexed and the individual walks on toes giving the equine appearance. In talipes calcaneus foot is dorsiflexed and walking is on heels. In talipes valgus, foot is everted and walking is on the medial border of foot. In talipes varus, foot is inverted and walking is on the lateral border of foot.
- Hallux valgus is a condition where there is hyperadduction of the great toe. The great toe passes under the second toe and so the head of the first metatarsal appears prominent. The transverse arch is malformed

Multiple Choice Questions

1. Joints of the pelvis are:
   a. Sacroiliac joints and pubic symphysis
   b. Lumbosacral joints, sacroiliac joints and pubic symphysis
   c. Lumbosacral joints and sacroiliac joints
   d. Sacro coccygeal, sacroiliac joints and pubic symphysis

2. Acetabular labrum:
   a. Is intracapsular
   b. Is rectangular in cross-section
   c. Has no cartilage cells
   d. Makes the joint weak

3. Iliofemoral ligament:
   a. Resists over extension of hip
   b. Is triangular in shape with an inferior apex
   c. Is separated from iliotrochanteric ligament by a bursa
   d Contributes to the backward swaying of the body

4 One of the following facts about fibular collateral ligament is false. Which one?
   a. It is called the extracapsular ligament of knee
   b. At its inferior attachment, it splits the tendon of biceps femoris
   c. It is separated from lateral meniscus by popliteus tendon
   d. It is taut in semiflexion of knee

5. Middle tibiofibular joint is:
   a. The tightly stretched interosseous membrane between tibia and fibula
   b. A recess extending from ankle into the distal tibiofibular joint
   c. Formed by the transverse tibiofibular ligament
   d. A joint of plane variety

6. Which ligament increases the proximal articular area of the ankle joint:
   a. Deltoid ligament
   b. Posterior talofibular ligament
   c. Transverse tibiofibular ligament
   d. Posterior talocalcaneal ligament

7. The axis of movement of subtalar joint:
   a. Passes through sinus tarsi
   b. Passes upwards and laterally
   c. Passes upwards
   d. Passes through sustentaculum tali

8. Spring ligament:
   a. Has deltoid ligament joining it on its superior surface
   b. Has tibialis posterior tendon turning direction beneath it
   c. Has a sling action for tibialis posterior
   d. Has an attachment on the anterior tubercle of calcaneus

9. Talus has its maximal stability:
   a Because it rests on the calcaneus
   b Because it forms the summit of medial longitudinal arch
   c. Because it transmits body weight to the bones of foot
   d. Because of its convex head

10. The ligament torn in inversion injury is:
   a. Deltoid ligament
   b. Lateral collateral ligament of ankle
   c. Spring ligament
   d. Short plantar ligament

ANSWERS

1. a **2.** a **3.** a **4.** d **5.** a **6.** c **7.** a **8.** b **9.** a **10.** b

Clinical Problem-solving

Case Study 1: A 24-year-old pregnant woman had ***swaying back*** of her spine. The backward swaying increased whenever she walked.

- ❑ Would you like to offer her any advice to correct this ***swaying back***?
- ❑ Which ligament is modified and which joint is affected?
- ❑ What is the reason for these changes?

Case Study 2: A 32-year-old football player sustained an injury to his right knee. His right medial meniscus had a bucket handle tear. His orthopaedician advised removal of the torn meniscal tissue by arthroscopy.

- ❑ Do you agree with the management advised?
- ❑ Why was the medial meniscus, and not the lateral, injured?
- ❑ Why cannot the torn meniscus be allowed to heal within the joint?

(For solutions see Appendix).

Chapter 30

Nerves of Lower Limb

Frequently Asked Questions

- Discuss the sacral plexus.
- Describe the posterior cutaneous nerve of thigh.
- Describe the course and distribution of sciatic nerve.
- Describe the course and distribution of tibial nerve.
- Describe the course and distribution of common peroneal nerve.
- Write notes on:
  - Medial plantar nerve,
  - Lateral plantar nerve,
  - Deep peroneal nerve,
  - Superficial peroneal nerve.

Several nerves of the lower limb are derived from the lumbar and sacral plexuses. The lumbar plexus is studied when abdomen is being detailed out. Let us now take up a detailed study of the sacral plexus.

SACRAL PLEXUS (FIG. 30.1)

The sacral plexus is formed by the ventral rami of the upper four sacral nerves (referred to as S1, S2, S3 and S4) along with the lumbosacral trunk (derived from L4 and L5). It is located on the posterolateral wall of the lesser pelvis, in front of piriformis muscle and outside the pelvic fascia. In front of the plexus are the internal iliac vessels and ureter. In addition to these, the pelvic colon on the left side and the coils of ileum on the right side are also related.

Nerves L4, L5, S1 and S2 each divide into anterior and posterior divisions. The posterior divisions of these nerves unite to form the common peroneal part of the sciatic nerve. The anterior divisions of these nerves along with S3 (which does not divide into anterior and posterior divisions) form the tibial part of the sciatic nerve. Part of nerve S4 joins branches from the ventral (anterior) divisions of S2 and S3 to form the pudendal nerve.

The plexus has several collateral branches and ends as two terminal branches, namely (1) ***sciatic branches*** and (2) ***pudendal branches***. The collateral branches can be grouped as (a) those arising from the anterior divisions and (b) those arising from the posterior divisions. The principal nerve arising from the plexus is in fact the sciatic nerve. The pudendal nerve, though technically a terminal branch, in comparison to the sciatic nerve is so small that it is usually classified as a branch arising from the anterior divisions.

Branches Arising from the Anterior Divisions (Fig. 30 2)

- Nerve to quadratus femoris and inferior gemellus (L4, L5, S1)
- Nerve to obturator internus and superior gemellus (L5, S1, S2)

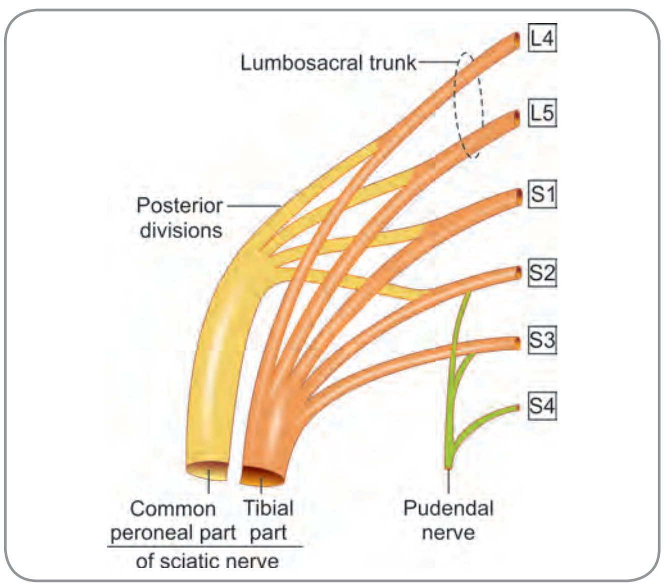


Fig 30.1: Basic plan of the sacral plexus

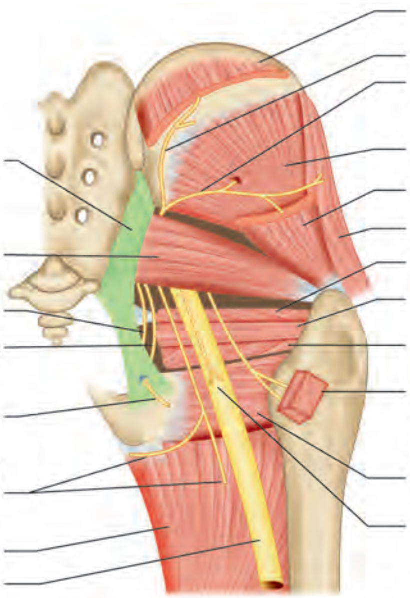


Fig. 30.2: Branches of sacral plexus seen in gluteal region

- Pelvic splanchnic nerves (S2, S3, S4)
- Pudendal nerve (S2, S3, S4)

Branches Arising from the Posterior Divisions

- Muscular branches to piriformis (S1, S2), coccygeus (S3, S4) and levator ani (S3, S4)
- Superior gluteal nerve (L4, L5, S1)
- Inferior gluteal nerve (L5, S1, S2)
- Perforating cutaneous nerve (S2, S3)
- Perineal branch of S4

Posterior Cutaneous nerve of thigh (posterior femoral cutaneous nerve) receives contributions from both the anterior (S2, S3) and posterior (S1, S2) divisions.

Of these branches, nerve to quadratus femoris and inferior gemellus, nerve to obturator internus and superior gemellus, superior gluteal nerve and inferior gluteal nerve have already been discussed in the gluteal region. We shall study the remaining nerves now.

Pelvic Splanchnic Nerves

They are two slender filaments composed of parasympathetic fibres. They arise from S2, S3 or from S3, S4 and pass forward to join the autonomic plexuses in the pelvis. Through these plexuses they are distributed to the pelvic viscera including the urogenital organs and large intestine.

Pudendal Nerve

This is the main nerve for supply of perineum. Except for a brief course, where it appears in the gluteal region, the pudendal nerve is a structure of lesser pelvis and perineum, hence is discussed in detail in that region.

Muscular Branches

- ***Nerve to piriformis*:** Arising usually from S2 and sometimes from S1 and S2, it immediately enters into the pelvic surface of the muscle.
- Nerves to coccygeus, levator ani and the perineal branch of S4 are nerves related to the pelvis and perineum. Hence, they are studied in the concerned areas.

Perforating Cutaneous Nerve

Arising from S2 and S3, this nerve is closely related to the lower roots of posterior cutaneous nerve (PCN) of thigh. It passes downwards and pierces the sacrotuberous ligament. Reaching the deep surface of gluteus maximus, it then winds around the inferior border or pierces the lower fibres of the muscle to become cutaneous. Once cutaneous, it supplies the skin and fascia of the lower gluteal region and he medial part of the gluteal fold. This nerve may not always be present as an independent nerve. It is very often incorporated into the pudendal nerve or into the gluteal branches of posterior of thigh

Posterior Cutaneous Nerve of Thigh

Also called the ***posterior femoral cutaneous nerve,*** PCN of thigh deserves a complete study, though it has been seen in parts in the gluteal region and back of thigh.

The PCN arises by two sets of roots. (1) The ***upper roots***, which are from the posterior divisions of S1 and S2, are closely related to the origin of the inferior gluteal nerve. (2) The ***lower roots***, which are from the anterior divisions of S2 and S3, are intimately related to the perforating cutaneous nerve or the pudendal nerve. As all the roots

unite, the nerve enters the gluteal region through the greater sciatic foramen, inferior to piriformis, along with the inferior gluteal nerve and vessels It runs downwards medial to the sciatic nerve and enters the thigh at the inferior border of the gluteus maximus muscle. Becoming gradually smaller as it descends, it runs over the hamstring muscles to the popliteal fossa. In the popliteal fossa, it finally pierces the deep fascia to become truly 'cutaneous' and divides into its multiple terminal branches.

The PCN gives out several branches, all of which are solely distributed to the skin and fascia. *The* ***gluteal branches,*** otherwise called the ***inferior nerves of the buttock***, are numerous and large in size. They are given out deep to the gluteus maximus and become subcutaneous by piercing the deep fascia along the inferior border of the muscle. They supply the skin and fascia of the inferior part of the buttock. The lateral set of gluteal branches reach till the level of the greater trochanter, overlap the terminal twigs of the lateral cutaneous nerve of thigh and the dorsal rami of L1, L2 and L3. The medial set of branches reach till the coccyx and overlap the branches of the perforating cutaneous nerve. The ***perineal branch*** arises at the lower border of gluteus maximus, runs medially and forward below the ischial tuberosity towards the perineum. It becomes subcutaneous near the pubic arch. In the male, its terminal branches supply the skin and fascia of the scrotum and root of penis while in the female, its branches supply the labium majus and the clitoris. The terminal twigs, in both sexes, communicate with the branches of the ilio-inguinal nerve. A few twigs from the perineal branch pass backwards towards the anus, and the perineal body also communicate with the inferior rectal and perineal branches of the pudendal nerve. As the main perineal branch courses to the perineum, it also gives a branch to the superomedial aspect of the thigh. The ***branches to thigh*** pierce the fascia lata at various levels and supply the skin and fascia of the back of thigh. The ***branches to the calf*** are two or three slender nerves, given out usually in the popliteal fascia. They pierce the deep fascia and supply the skin and fascia of the calf till about the middle of the leg. They communicate with the sural nerve. In rare situations, they may extend till the ankle.

SCIATIC NERVE

Origin, Course and Relations

The principal nerve arising from the sacral plexus is also the thickest nerve of the body. It actually consists of two ***nerves***, namely (1) **tibial** and (2) **common peroneal** ***nerves***, which are bound together by an investing sheath. It receives fibres from spinal nerves L4 to S3. It passes from the pelvis to the gluteal region through the greater sciatic foramen, below the piriformis. It descends through the gluteal region into the back of the thigh. At the junction of the middle- and lower-thirds of the thigh, the sciatic nerve ends by dividing into the tibial and common peroneal nerves. The level of division is, however, variable.

As it runs downwards in the gluteal region, with a slight lateral curve, it is between the ischial tuberosity and the greater trochanter of femur. In the gluteal region, it is covered posteriorly by the gluteus maximus and lies successively on the posterior surface of the ischium, the superior gemellus, the obturator internus, the inferior gemellus and the quadratus femoris. The nerve to quadratus femoris is deep to the sciatic nerve here.

The nerve enters the thigh at the lower border of quadratus femoris. Initially, it lies in the angle between the gluteus maximus superolaterally and the hamstrings medially. In the thigh the nerve lies upon the adductor magnus, and is crossed superficially (i.e., posteriorly) by the long head of the biceps femoris.

It usually terminates at the superior angle of the popliteal fossa by dividing into the tibial and common peroneal nerves.

Branches (Fig. 30.3)

As the sciatic nerve emerges out of its origin, it usually is a broadband with four constituents. From medial to lateral, these constituents are: (1) the nerve to hamstrings, (2) the tibial nerve, (3) the common peroneal nerve and (4) the nerve to short head of biceps femoris. The nerve to hamstrings is actually a branch of the tibial component and the nerve to short head of biceps, a branch of the common peroneal.

- ***Nerve to hamstrings:*** It forms the most medial part of the sciatic trunk. It arises from all roots of the tibial nerve from their anterior aspects, namely, L4, L5, S1, S2 and S3. The different roots merge into a thick cord which is, at first closely related to the tibial nerve. Immediately inferior to the quadratus femoris, it leaves the tibial and gets distributed to the hamstrings muscles. The individual twigs to the muscles vary in length and number. The nerve to semitendinosus is usually double The nerve to semitendinosus may a so give the branch to the long head of biceps. The nerve to semimembranosus arises in common with the nerve to the ischial portion of adductor magnus.
- ***Nerve to the short head of biceps femoris***: It arises from L5, S1 and S2 and springs from the lateral part of the sciatic trunk in the proximal or middle part of thigh. Until its separation, it is closely associated with the common peroneal component. It supplies the short head of biceps which is not a hamstring by definition.
- ***Articular branch to knee:*** It originates from L4, L5 and S1. It branches from the common peroneal at the point where the nerve to short head springs out. It runs under cover of the biceps muscle in the superolateral

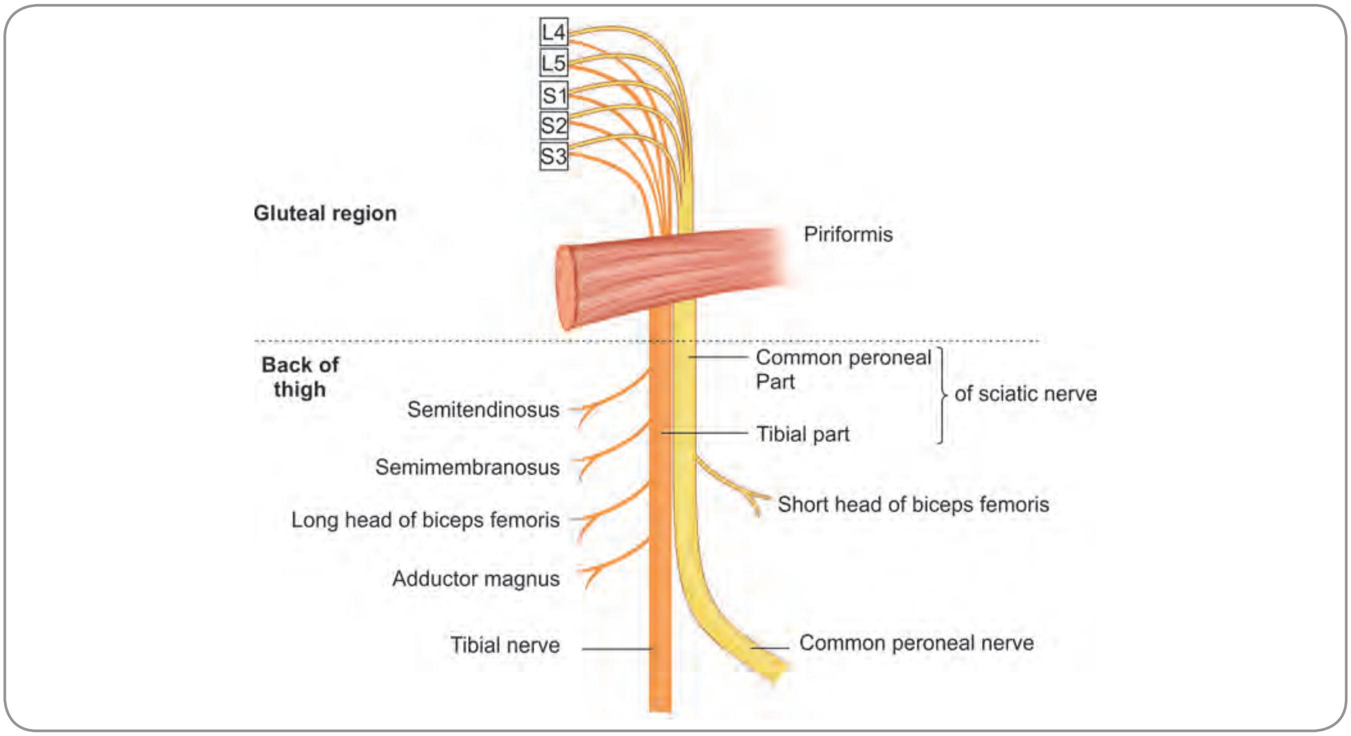


Fig. 30.3: Branches of sciatic nerve in the thigh

boundary of the popliteal fossa and divides above the lateral angle of the fossa into a proximal and a distal branch. The two branches accompany the superior and inferior lateral genicular arteries respectively to enter into the knee joint and supply the structures within.

Terminal Branches of the Sciatic Nerve

The ***tibial*** and the ***common peroneal*** are the two terminal branches of the sciatic nerve. They result from the combination of the anterior and posterior cords respectively of the sacral plexus.

Clinical Correlation

- The sciatic nerve can be injured by carelessly given intramuscular injections in the gluteal region. (This can be avoided by giving injections only in the upper and lateral part of the gluteal region). The nerve can also be injured in fractures of the pelvis and dislocations of the hip joint.
- Injury to the nerve paralyses muscles of the back of the thigh (hamstrings), and all muscles of the leg and foot.
- Where the foot hangs downwards (by its own weight), the condition is called ***foot drop***. Foot drop is also caused by injury to the common peroneal nerve. There is sensory loss over the greater part of the leg and foot, but the area supplied by the saphenous branch of the femoral nerve is spared
- Pressure on the lumbosacral nerve roots is often produced by prolapse of an intervertebral disc. Typically, the condition causes severe pain that begins in the gluteal region and radiates down the back of the leg to reach the foot. The condition is called ***sciatica***.

TIBIAL NERVE

This nerve is otherwise called the ***medial popliteal nerve*** and the ***posterior tibial nerve***. It arises from the anterior divisions of L4, L5, S1, S2 and S3 and runs as a part of the sciatic trunk in the gluteal region and proximal thigh. At the superior angle of popliteal fossa, where the sciatic trunk divides into its constituent parts, the tibial nerve separates off and runs downwards to the leg. It continues further downwards and at the level of the ankle, takes a medial turn to go under cover of the flexor retinaculum, where it divides into its two terminal branches, namely (1) the medial and (2) the lateral plantar nerves.

Course and Relations

In the gluteal region, where it is a part of the sciatic trunk, the tibial nerve is between the ischial tuberosity and the greater trochanter of femur. In this region, it is covered posteriorly by the gluteus maximus and lies successively on the posterior surface of the ischium, the superior gemellus, the obturator internus, the inferior gemellus and the quadratus femoris. The nerve to quadratus femoris forms a deep relation.

The nerve (still as a part of the sciatic trunk) enters the thigh at the lower border of quadratus femoris. Initially, it lies in the angle between the gluteus maximus superolaterally and the hamstrings medially. In the thigh the nerve lies upon the adductor magnus, and is crossed superficially (i.e., posteriorly) by the long head of the biceps femoris.

In the popliteal fossa, where it is separated from the common peroneal nerve, it first lies under cover of the semimembranosus muscle. Then it becomes almost superficial, immediately deep to the fascia. It passes further downwards over the popliteal vessels, crossing them from lateral to medial side. Then it comes to lie on the popliteus muscle, under cover of gastrocnemius and plantaris.

As the nerve enters the back of leg, it passes deep to the soleus muscle and rests on the tibialis posterior muscle and the posterior aspect of tibia. Accompanied by the posterior tibial vessels, it runs on the intermuscular septum separating the superficial muscles from the deep muscles of the posterior compartment of leg In its course to the ankle, the nerve is first medial and then lateral to the posterior tibial vessels. As it crosses the ankle, it takes a medial deviation and lies midway between the medial malleolus and calcaneus. At this level, it comes under cover of the flexor retinaculum and lies between the tendons of flexor digitorum longus and flexor hallucis.

Branches (Fig. 30 4)

The branches of the tibial nerve can be considered under three groups namely—

1. ***Branches when the tibial nerve is incorporated in the sciatic trunk:*** The two branches at this level are the nerve to hamstrings and the articular branch to knee.

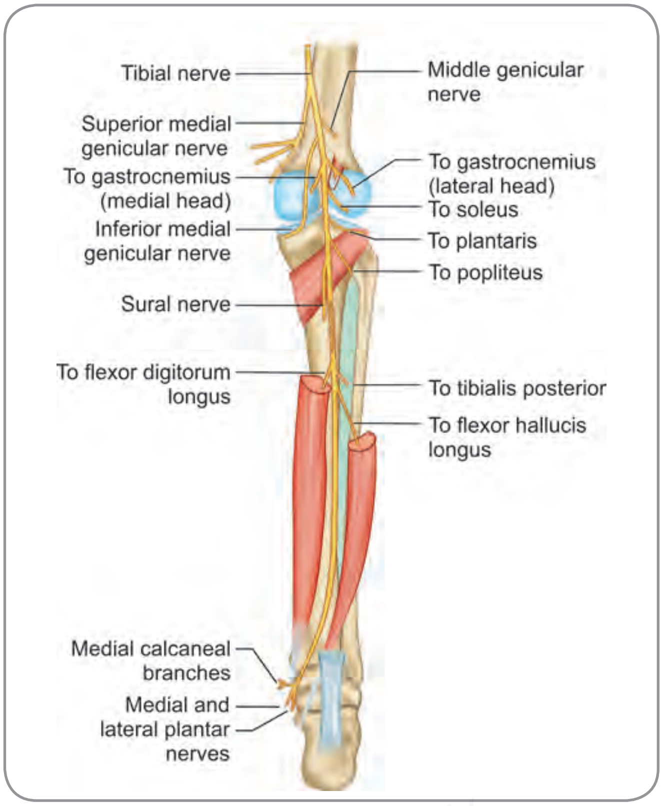


Fig. 30.4: Branches of the tibial nerve

2. ***Branches in the popliteal fossa***: These can be grouped into three sets:
   - ***Articular branches to the knee***: Two slender branches, one of which pierces the oblique popliteal ligament and the other accompanies the inferomedial genicular artery; both supply the structures of the knee joint.
   - ***Muscular branches***: Five branches; the branches to the two heads of gastrocnemius and the plantaris enter the concerned muscles at those aspects where they form the inferior borders of the popliteal fossa; the nerve to soleus enters the muscle on its superficial surface; the remaining nerve of this set, namely, the nerve to popliteus deserves special description. The nerve runs down on the posterior surface of the popliteus muscle, turns round its distal border and then supplies the muscle on its anterior surface. This nerve, as it turns round the distal border of the muscle, gives out muscular branches to the tibialis posterior, a branch to the interosseous membrane, an articular branch to the tibiofibular syndesmosis and a medullary branch to the tibia.
   - ***Cutaneous branch***: This is the sural nerve; from the popliteal fossa, the nerve runs between the two heads of gastrocnemius and then lies on the tendocalcaneus It pierces the deep fascia in the middle third of the leg and becomes cutaneous. It is immediately joined by the peroneal communicating branch of the common peroneal nerve. It then runs downwards and reaches the foot by winding around the back of the lateral malleolus, along with the small saphenous vein. The sural nerve gives cutaneous branches to the lateral aspect and back of the lower third of the leg, the ankle, the heel (the lateral calcaneal branches) and the lateral border of the foot and the little toe, articular branches to ankle and tarsal joints. On the dorsum of the foot, the sural nerve communicates with the branches of the superficial peroneal nerve. Through this communication, it may reinforce or replace those branches of the superficial peroneal nerve to the adjacent sides of the 4th and 5th or the 3rd and 4th toes.
3. ***Branches in the leg:*** These are the muscular, cutaneous and terminal sets.
   - ***Muscular branches:*** These are usually four in number, namely (1) the nerve to soleus, (2) nerve to tibialis posterior, (3) nerve to flexor digitorum longus and (4) the nerve to flexor hallucis longus. The first two may arise from a common trunk. The nerve to flexor hallucis longus usually accompanies the peroneal artery and also supplies it.
   - ***Cutaneous branches:*** These are the medial calcaneal branches, which pierce the flexor retinaculum to

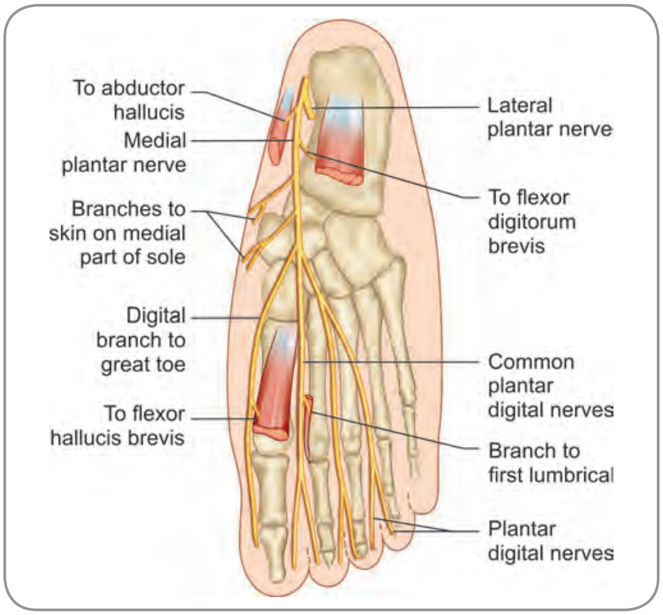


Fig. 30.5: Distribution of medial plantar nerve

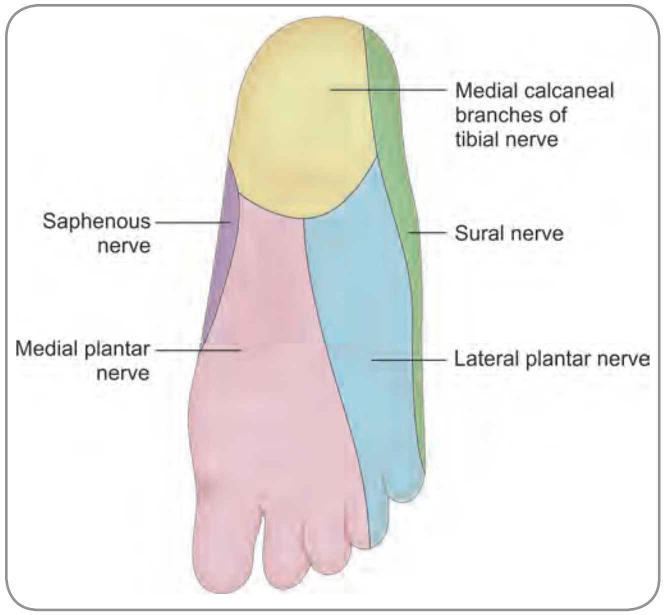


Fig. 30.6: Nerves supplying the skin of sole

supply the skin and fascia of the heel and posterior part of the sole. A medullary branch to the fibula and an articular branch to the ankle joint are also given by the tibial nerve.

- ***Terminal branches:*** These are the medial and lateral plantar nerves.

Medial Plantar Nerve

The medial plantar nerve is the larger of the two terminal branches of the tibial nerve. Starting from under cover of the flexor retinaculum, it courses forward in the sole deep to abductor hallucis and reaches the interval between the abductor hallucis and the flexor digitorum brevis. The nerve is accompanied by the medial plantar vessels and ends by dividing into its four terminal branches.

Branches (Fig. 30.5)

Apart from its terminal branches, the medial plantar nerve gives out collateral branches which can be classified into four sets.

- ***Muscular branches:*** These supply the abductor hallucis and the flexor digitorum brevis.
- ***Cutaneous branches:*** Otherwise called the ***plantar cutaneous branches***, they pierce the deep fascia in the interval between the abductor hallucis and the flexor digitorum brevis and supply the medial part of the sole of the foot (Fig. 30.6).
- ***Articular branches:*** They supply the tarsal and tarsometatarsal joints.
- ***Vascular branches:*** They supply the neighbouring arteries.

***Terminal branches of the medial plantar nerve*:** These are the four common plantar digital nerves and are numbered from the medial to the lateral.

- The ***first branch*** separates off from the main nerve before the other terminal branches, runs forward in the interval between the abductor hallucis and the flexor digitorum brevis, supplies a branch to the latter muscle and then pierces the deep fascia just posterior to the ball of the big toe. It gives cutaneous branches to the medial side of the foot and ends as the plantar digital nerve for the medial side of the big toe.
- The ***second branch*** arises with the third and the fourth from the main nerve. It supplies a branch to the first lumbrical and then becomes superficial by piercing the deep fascia in the interval between the first and the second toes. It ends by dividing into two plantar digital nerves for the adjacent sides of the first and the second toes.
- The ***third and the fourth branches*** coursing a little laterally, supply small twigs to the joints of the foot and then become superficial in the intervals between the second and third and the third and fourth toes respectively. Once superficial, they divide into the plantar digital nerves for the adjacent sides of these toes.

Lateral Plantar Nerve

This is the smaller of the two terminal branches of the tibial nerve. Starting from under cover of the flexor retinaculum, it runs forwards and laterally across the sole, deep to the flexor digitorum brevis and superficial to the flexor digitorum accessorius towards the base of the fifth metatarsal bone Through its course, it is medial to the

lateral plantar artery. As it reaches the base of the fifth metatarsal bone, it divides into the superficial and deep terminal branches.

Branches (Fig. 30.7)

Apart from its terminal branches, the lateral plantar nerve gives out collateral branches which can be classified into three sets.

- ***Muscular branches:*** These supply the flexor digitorum accessorius and the abductor digiti minimi.
- ***Cutaneous branches:*** They pierce the deep fascia in the interval between the flexor digitorum brevis and abductor digiti minimi and supply the lateral part of the sole of the foot (Fig. 30.6).
- ***Vascular branches:*** They supply the neighbouring arteries.

Terminal branches of the lateral plantar nerve: There are two terminal branches, namely (1) the superficial and (2) the deep branches. Both of them give articular branches to the joints of the foot.

The superficial branch passes forward in the interval between the flexor digitorum brevis and the abductor digiti minimi and divides into the medial and lateral common plantar digital branches. The medial common plantar digital branch runs forward further to the space between the fourth and the fifth toes, becomes cutaneous and then divides into two plantar digital branches to the adjacent sides of these toes. It communicates with the fourth terminal branch of the med al plantar nerve. The lateral common plantar digital branch, after supplying the flexor digiti minimi and the interossei of the fourth space, becomes superficial behind the ball of the little toe,

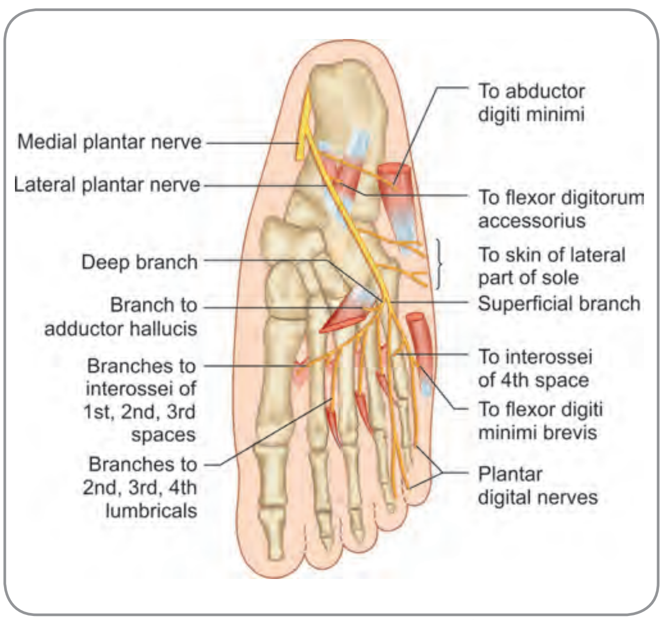


Fig. 30.7: Distribution of lateral plantar nerve

supplies cutaneous twigs to the lateral side of the sole and finally ends as the plantar digital nerve for the lateral side of the little toe

The deep branch turns medially towards the big toe lying deep to the flexor digitorum accessorius and the adductor hallucis. It supplies the tarsal and tarsometatarsal joints, the interossei muscles, the adductor hallucis muscle and the lateral three lumbrical muscles. All the muscular branches enter the deep surface of the muscles.

Plantar Digital Nerves (Fig. 30.5)

The plantar digital nerves supply the entire length of the toe on the plantar surface; at the level of the distal phalanges, they give dorsal twigs which supply the nailbeds, nails and tips of the toes on their dorsal surfaces. The digital nerves also supply the metatarsophalangeal and interphalangeal joints.

COMMON PERONEAL NERVE

This nerve is otherwise called the ***lateral popliteal nerve***. It arises from the posterior divisions of L4, L5, S1 and S2. It forms part of the sciatic nerve in the gluteal region and the posterior thigh. From the bifurcation of the sciatic nerve at the superior angle of the popliteal fossa, the common peroneal nerve reaches its termination about an inch distal to the head of fibula.

Course and Relations

In the gluteal region, where it is a part of the sciatic trunk, the common peroneal nerve is between the ischial tuberosity and the greater trochanter of femur. In this region, it is covered posteriorly by the gluteus maximus and lies successively on the posterior surface of the ischium, the superior gemellus, the obturator internus, the inferior gemellus and the quadrates femoris. The nerve to quadratus femoris forms a deep relation.

The nerve (still as a part of the sciatic trunk) enters the thigh at the lower border of quadratus femoris Initially, it lies in the angle between the gluteus maximus superolaterally and the hamstrings medially. In the thigh the nerve lies upon the adductor magnus, and is crossed superficially (i.e., posteriorly) by the long head of the biceps femoris.

In the popliteal fossa, where it separates off from the tibial nerve, it is first under cover of the biceps femoris muscle. Following the tendon of this muscle, the nerve runs obliquely to the lateral part of the popliteal fossa and passes over the lateral head of gastrocnemius to reach the back of the head of fibula. As it reaches the fibula, the nerve lies quite superficial. Only at its termination, it is covered by the peroneus longus muscle and is actually between the neck of fibula around which it winds and the muscle.

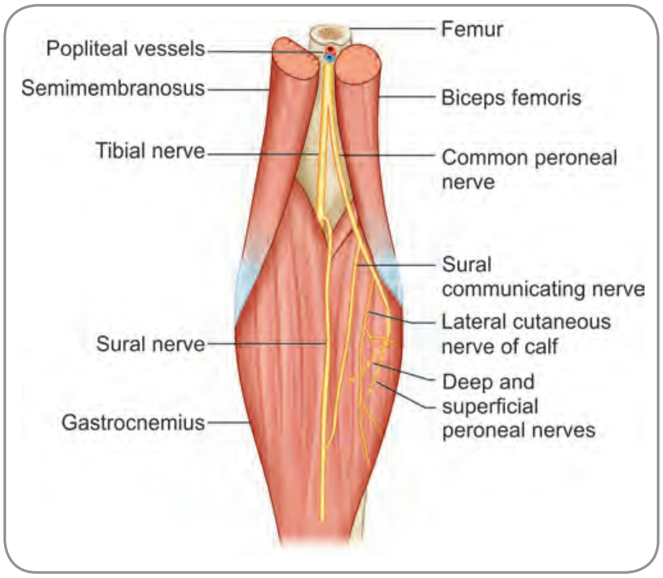


Fig. 30.8: Distribution of the common peroneal nerve

Branches (Fig. 30.8)

The branches of the common peroneal nerve can be considered in two groups, namely:

1. ***Branches when the common peroneal is incorporated in the sciatic trunk***: The two branches at this level are the nerve to short head of biceps and the articular branch to knee.
2. ***Branches in the popliteal fossa***: These can be grouped into two sets.

- ***Cutaneous branches:*** The two cutaneous branches in this category are the lateral cutaneous nerve of the calf and the peroneal communicating nerve.
  - ***Lateral cutaneous nerve of the calf:*** It may be a single nerve or more in number. It arises in common with the peroneal communicating nerve in the popliteal fossa, pierces the deep fascia over the lateral head of gastrocnemius and supplies the skin and fascia of the lateral part of the back of leg in the upper two-thirds.
  - ***Peroneal communicating branch:*** It arises in the popliteal fossa, passes over the lateral head of gastrocnemius but deep to the deep fascia and reaches the middle third of the leg. It joins the sural nerve in the middle third.
- ***Recurrent branch***: It arises immediately proximal to the terminal division of the common peroneal and passes forward under cover of the peroneus longus. It then runs through the extensor digitorum longus and reaches the anterior compartment of leg below the lateral condyle of tibia. At this level, it divides into branches which supply the tibialis anterior muscle, the superior tibiofibular joint and the knee joint.
  - ***Terminal branches of the common peroneal nerve:*** These are the superficial and deep peroneal nerves. They arise immediately below the head of fibula and under cover of peroneus longus, run forward and subsequently diverge from one another.

Deep Peroneal Nerve

This nerve is otherwise called the ***anterior tibial nerve***. It reaches the anterior compartment of the leg under cover of the peroneus longus and the extensor digitorum longus. It passes downwards and medially, enters the anterior compartment of the leg and accompanied by the anterior tibial artery, descends in front of the interosseous membrane, first between the tibialis anterior and extensor digitorum longus and then between the tibialis anterior and extensor hallucis longus. It is crossed by the extensor hallucis at the ankle. In the lower part of the leg, the nerve (along with the accompanying artery) takes a slight medial swerve The tibia also widens here. Because of these two reasons, the deep peroneal nerve (and its accompanying artery) runs down on the anterior aspect of the shaft of the tibia. Still accompanied by the anterior tibial artery, it reaches the front of the ankle joint. It ends here by dividing into lateral and medial terminal branches.

Branches (Fig. 30.9)

These are in three sets, namely (1) the muscular branches, (2) the articular branch and (3) the terminal branches.

1. ***Muscular branches:*** These are given off to the muscles of the anterior compartment of the leg, namely the tibialis anterior, the extensor hallucis longus, the extensor digitorum longus and the peroneus tertius.
2. ***Articular branch:*** A fine articular twig is given off to the ankle joint.

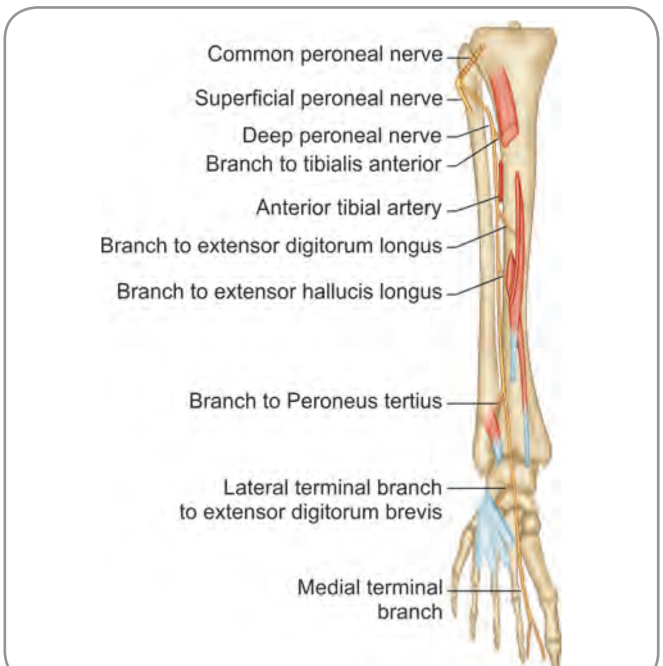


Fig. 30.9: Distribution of deep peroneal nerve

3. ***Terminal branches:*** They are two in number and are (2) the ***medial*** and (2) the ***lateral terminal branches***. For a great part, the medial terminal branch is a cutaneous nerve. It passes over the dorsum of the foot, along the lateral side of the dorsalis pedis artery. On reaching the first intermetatarsal space, it divides into two dorsal digital branches which supply the adjacent sides of the big toe and the second toe. Each of these branches can communicate with the branches of the superficial peroneal nerve and also give twigs to the joints of the foot. The medial terminal branch also supplies the first dorsal interosseous muscle and the metatarsophalangeal joint of the great toe The lateral terminal branch, in essence is a muscular branch. It passes under cover of the extensor digitorum brevis over the tarsus and ends in a gangliform enlargement. Muscular branches from this enlargement supply the extensor digitorum brevis and articular branches supply the joints of the foot. One of the articular branches is seen to give twigs to the second and sometimes the third dorsal interosseous muscle.

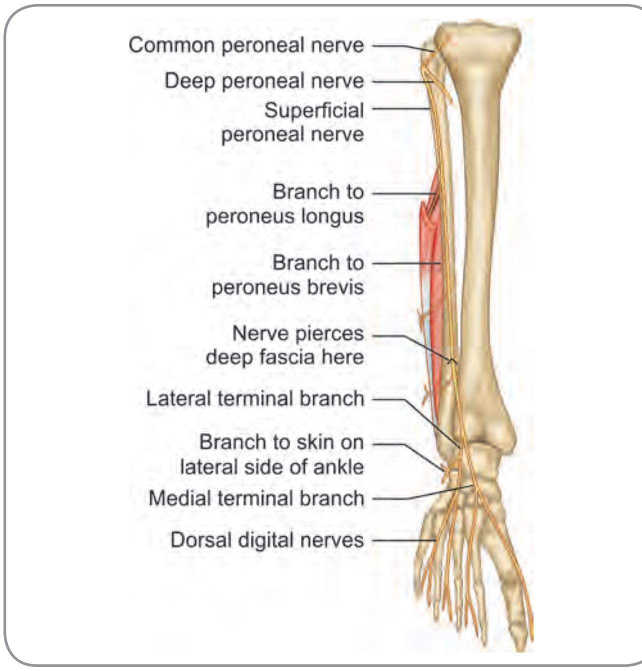


Fig. 30.10: Distr bution of superficial peroneal nerve

Superficial Peroneal Nerve

The superficial peroneal nerve, also called the ***superficial fibular nerve*** or the ***musculocutaneous nerve***, is the smaller of the two terminal branches of the common peroneal nerve. It begins at the neck of the fibula deep to the peroneus longus. It runs downwards and obliquely forwards on the shaft of fibula until it reaches the peroneus brevis muscle. At the junction of the middle and the lower thirds of the leg, the nerve becomes cutaneous. Just above the ankle, it divides into medial and lateral terminal branches that descend across the ankle to reach the dorsum of the foot.

Branches (Fig. 30.10)

These are in two sets, namely (1) the muscular and (2) the cutaneous branches.

- ***Muscular branches:*** These branches which are given out in the upper part of the lateral compartment of the leg supply the two muscles of the compartment (peroneus longus and the peroneus brevis).
- ***Cutaneous branches*:** These are the terminal cutaneous branches and are called the ***medial*** and the ***intermediate dorsal cutaneous branches***. The medial dorsal cutaneous branch runs down over the extensor retinacula, supplies twigs to the skin and fascia of the distal third of the leg and the dorsum of the foot and then divides into two dorsal digital branches. One dorsal digital branch supplies the medial side of the big toe; and another supplies the adjacent sides of the second and third toes. The intermediate dorsal cutaneous nerve (which is the lateral terminal cutaneous branch of the superficial peroneal nerve) also passes over the extensor retinacula, supplies branches to the distal part of the leg and the dorsum of the foot and then divides into two dorsal digital branches which supply the adjacent sides of the third and fourth and the fourth and fifth toes.

The cutaneous nerves on the dorsum of the toes are smaller than their plantar counterparts. On the dorsum of the terminal phalanges they are reinforced by twigs from plantar nerves which supply the tips of toes and nails.

Added Information

- Whenever the sciatic nerve is divided into its component parts at the origin itself, the PCN of thigh is also in two parts: (1) ***an anterior part***, associated with the tibial nerve and comprising the branches to perineum and medial aspect of lower limb, and (2) ***a posterior part***, associated with the common peroneal nerve and comprising the branches to the gluteal region and the lateral part of posterior thigh and leg.
- The sciatic nerve may divide into its terminal branches at varying levels. The two branches may even be separate at their origin, in which case the common peroneal usually pierces the piriformis muscle.
- The tibial nerve is a homologue of the median-ulnar conjoined trunk of the upper limb The common peroneal is a homologue of the radial nerve
- The medial plantar nerve is the homologue of the median nerve in the hand.
- The lateral plantar nerve is the homologue of the ulnar nerve in the hand.

Multiple Choice Questions

1. Relations of sacral plexus are:
   a. Piriformis and ureter posteriorly, internal iliac vessels anteriorly
   b. Piriformis posteriorly, internal iliac vessels and ureter anteriorly
   c. Piriformis and internal iliac vessels posteriorly, ureter anteriorly
   d. Piriformis and internal iliac vessels anteriorly, ureter posteriorly
2. Regarding posterior cutaneous nerve (PCN) of thigh, one is false. Which one?
   a. PCN arises by two sets of roots
   b. PCN passes through the greater sciatic foramen inferior to piriformis
   c. PCN runs lateral to sciatic nerve
   d. All the branches of PCN are distributed to skin and fascia
3. The posterior tibial nerve:
   a. Is otherwise called the lateral popliteal nerve
   b. Lies deep to semimembranosus muscle in the upper part of popliteal fossa
   c. Is superficial to soleus and tibialis posterior
   d. Does not give any cutaneous branch
4. The common peroneal nerve:
   a. Is a homologue of radial nerve
   b. Arises from anterior division of L4, L5 and S1
   c. Runs superficial to head of biceps femoris muscle
   d. Gives a recurrent branch which passes superficial to peroneus longus
5. The perforating cutaneous nerve:
   a. Is related to upper roots of posterior cutaneous nerve
   b. Pierces the sacrotuberous ligament
   c. Supplies skin of superolateral gluteal region
   d Gets often incorporated into posterior cutaneous nerve

ANSWERS

1. b **2.** c **3.** b **4.** a **5.** b

Clinical Problem-solving

Case Study 1: A 64-year-old woman complained of pins and needles in her left gluteal region. In due course, altered sensations gave way to intense pain. The pain radiated down the back of leg. No other external abnormality or injury could be seen.

- What would you suspect in this case?
- What is the usual cause for it?
- What exactly happens and how are the symptoms produced?

Case Study 2: A 52-year-old man suffered a fibular fracture on the right side. His right leg was put on a plaster cast to keep the fractured bone in position. On removal of the cast, he complained of weakness of all leg muscles and altered sensations over most part of leg and dorsum of foot. On examination, it was found that he had inability to dorsiflex, invert and evert his foot.

- What structure has been affected?
- What is the probable cause?
- How would you substantiate your answer?

(For solutions see Appendix).

Chapter **31**

Cross-Sectional, Radiological and Surface Anatomy of Lower Limb

Frequently Asked Questions

- Draw a diagram showing the cross section of thigh at the level of apex of femoral triangle. Discuss the clinical significance.
- Write notes on
  - Neck-shaft angle of femur,
  - Shenton's line,
  - Features in a normal radiograph of femoral region,
  - Supernumerary bones of lower limb.

CROSS-SECTIONAL ANATOMY OF LOWER LIMB

The lower limb consists of large muscles which make up the bulk of it and neurovascular structures which run in intervals between these muscles.

Due to the large size of the muscles, considerable lengths of the limb show similar and related features. It is easy to study the cross sectional pattern of the lower limb in three sections of the thigh, two sections of the knee joint and two sections of the leg.

TRANSVERSE SECTION OF THIGH AT THE LEVEL OF THE APEX OF FEMORAL TRIANGLE (FIG. 31.1)

This section shows most of the muscles and so the section appears full and bulky. Since the muscle bulk is more posterior, femur appears to be pushed anterolaterally.

Closely approximated to the anterior, lateral and medial aspects of the bone are the vasti muscles. Rectus femoris appears as an ovoid mass, closely resting on the vasti, on the anteromedial aspect. Medial to rectus is the Sartorius.

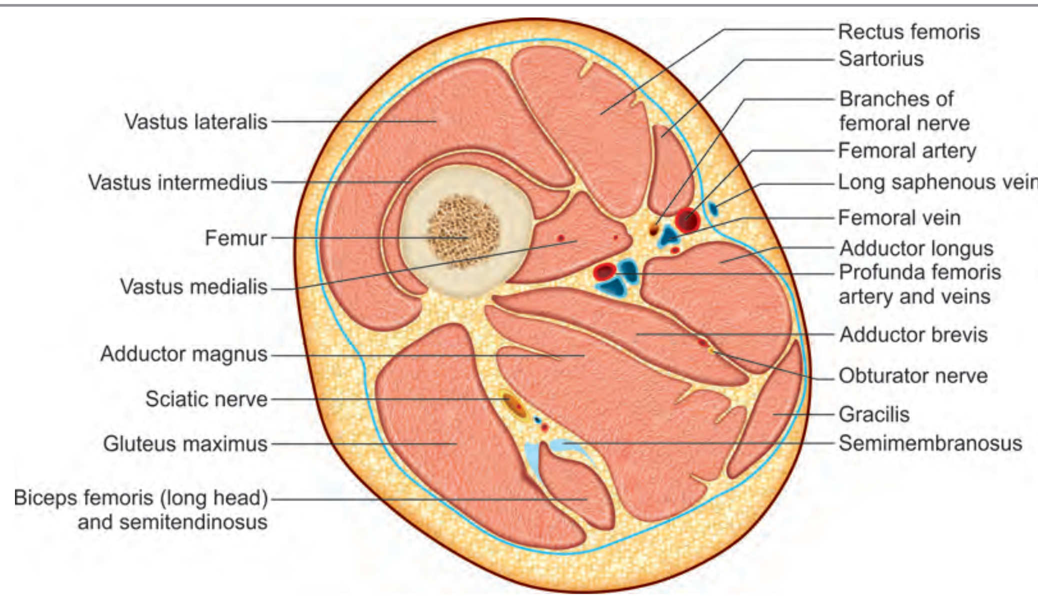


Fig. 31.1: Transverse section of left thigh at the level of the apex of femoral triangle (seen from above)

The cut end of an imaginary vertical plane running across the thigh can be seen to define the neurovascular structures at this section. This plane passes posterior to the anterior compartment muscles; at the medial and lateral edges of this plane, the deep fascia can be seen to indent slightly and send in the medial and the lateral intermuscular septa. The plane is actually the line of cleavage between the anterior compartment anteriorly and the adductor and posterior compartments posteriorly. The adductor group muscles (Adductor longus, Adductor brevis, Adductor magnus and Gracilis) lie posterior to this plane; Pectineus is not seen at this level. The lateral part of the dividing plane is fibrous; the medial part shows many of the neurovascular structures and forms a dense roof over the femoral vessels as they course into the adductor canal Between the Rectus and Sartorius anteriorly and the Adductores longus and brevis posteriorly, the femoral artery and femoral vein are seen in a pool of connective tissue. The connective tissue pool indicates the commencement of the adductor canal and the vessels are seen as they course into the canal. The artery is superficial (and medial) to the vein. Lying anterior to the vein, are the branches of the femoral nerve The great saphenous vein is seen superficial (and medial) to the deep fascia. Deeper to (more laterally) but lying in the same oblique plane are the profunda vessels consisting of the profunda femoris artery and its venae comitantes. These vessels lie between the vastus medialis in front and the Adductor brevis behind.

Branches of the obturator nerve can sometimes be seen between the adductor group of muscles.

Muscles of the posterior compartment occupy the posterolateral aspect of the thigh and appear to be pushed laterally by the medial group. Gluteus maximus forms a major bulk on the posterolateral aspect; the Biceps femoris along with the tendons of Semitendinosus and semimembranosus is seen sandwiched between the Gluteus and the Adductor magnus. Sciatic Nerve runs in the interval between the Adductor magnus and the posterior muscles.

Significance of the level: The major vessels of the lower limb lie in a row in the same oblique plane. In an abducted and laterally rotated limb, a penetrating injury at this level can damage all the vessels and since all of them are likely to bleed profusely, fatality is high. In olden days, butchers, sitting with both thighs abducted and laterally rotated, kept the cutting board in between their thighs and cut the meat. When hard pieces of meat were cut, it was likely that the knife cut into the thigh of the butcher himself, resulting in fatal injuries. Hence, the level is sometimes dubbed ***'the level of the butcher's thigh.'***

TRANSVERSE SECTION AT THE MIDDLE OF THIGH (FIG. 31.2)

This section shows the muscles of thigh; the adductor canal is well defined.

The three vasti surround the Femur in close approximation and the Rectus femoris lies over the Vastus intermedius in an interval between the Vastus medialis and the lateralis. Adductor longus lies immediately posterior to the Vastus medialis. A muscular gutter is created between these two muscles and the Femoral vessels with the Nerve to Vastus lateralis and the saphenous nerve run in this gutter. The gutter is closed superficially by the Sartorius,

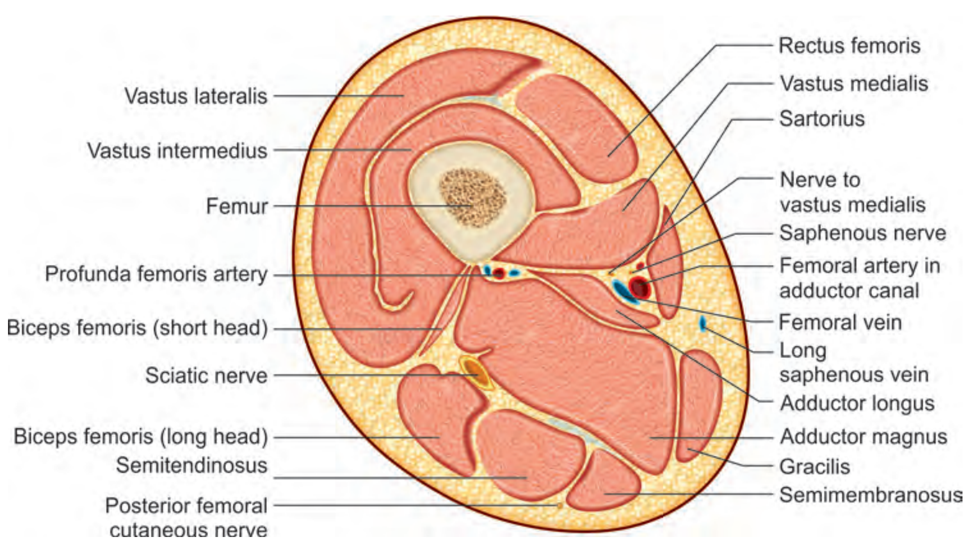


Fig. 31.2: Transverse section through the middle of left thigh (seen from above)

thus completing the formation of the Subsartorial adductor canal. The canal is seen to have anteromedial, anterolateral and posteromedial walls formed respectively by the Sartorius, Vastus medialis and Adductor longus muscles. The great saphenous vein is superficial to Sartorius.

Lying close to the posterior aspect of femur (almost touching the medial lip of linea aspera) are the profunda femoris vessels. Adductor magnus stretches across the posterior aspect from the linea aspera. Semimembranosus, Semitendinosus and Biceps femoris (long head) lie behind the Adductor magnus as a continuous muscle mass from medial to lateralwards. Sciatic nerve is seen between the Adductor longus and the long head of Biceps. Short head of biceps is seen as a thin strip close to the lateral lip of linea aspera.

TRANSVERSE SECTION OF THE THIGH IMMEDIATELY ABOVE ADDUCTOR TUBERCLE (FIG. 31.3)

A section of the lower thigh at this level shows a transverse section of the suprapatellar bursa and the popliteal fossa

The femur is almost at the centre with a slight anterior shift. Immediately anterior to the femur is seen the suprapatellar bursa and still anterior the quadriceps tendon. Vastus medialis and Vastus lateralis are seen on the medial and lateral aspects of the bone respectively, though the medialis is larger than the lateralis. Adductor magnus is seen as a thin strip mainly composed of aponeurotic tissue immediately behind vastus medialis. Sartorius, at this level, is posterior to adductor magnus and posterior to Sartorius is Semimembranosus. The tendons of Gracilis and Semitendinosus are seen on the medial and posterior aspects of semimembranosus respectively.

Lying posterior to vastus lateralis are the two heads of Biceps femoris, the long head being superficial. Considerable mass of connective tissue admixed with fat can be made out posterior to femur and in the interval between the medial muscle mass (consisting of semimembranosus and Sartorius) and the lateral muscle mass (consisting of the two heads of biceps femoris). Embedded within the fat laden connective tissue are the Popliteal vessels, tibial and common peroneal nerves. The popliteal artery is at the centre of the connective tissue mass with the popliteal vein lying lateral to it. The tibial and common peroneal nerves are seen superficial to the vein. The small saphenous vein and the posterior cutaneous nerve of thigh are seen more superficially. The saphenous nerve and the descending genicular artery may be seen between Sartorius and adductor magnus.

TRANSVERSE SECTION OF THE KNEE JUST ABOVE THE PATELLA

The section also cuts through the popliteal fossa. The femur is placed centrally. Fibres of vastus medialis and lateralis are seen on either side with the medial and lateral patellar retinacula connecting them to the anteriorly placed quadriceps tendon.

The posterior part of the section is wider than the anterior part. On the lateral aspect of the posterior part is the ovoid shaped section of Biceps femoris. On the medial aspect are the Semimembranosus and Sartorius. Tendon of semitendinosus is seen posterior to semimembranosus

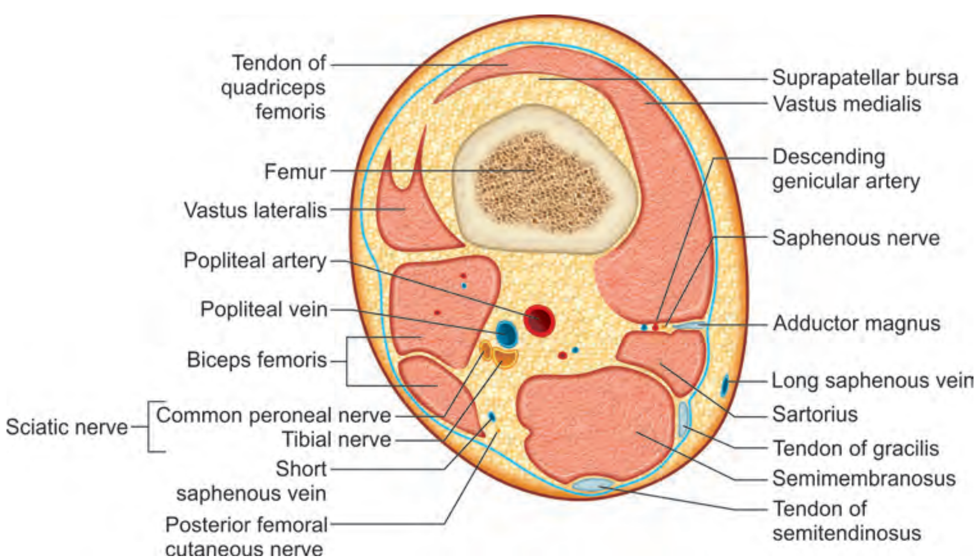


Fig. 31.3: Transverse section of the thigh, above the adductor tubercle (seen from above)

and the gracilis muscle is seen lateral to Sartorius. In the fat laden connective tissue on the posterior aspect of the femur are the (from medial to lateral) popliteal artery, popliteal vein and tibial nerve. The common peroneal nerve is seen on the medial aspect of Biceps femoris.

TRANSVERSE SECTION OF THE KNEE AT THE LEVEL OF FEMORAL CONDYLES

The presence of patella gives an anterior prominence to this section. Most of the section is occupied by the femur. The medial and lateral condyles of femur are clearly made out with the abutting anterior aspect of the lateral condyle. The intercondylar fossa is conspicuous and lying immediately posterior to the medial and lateral condyles are the medial and lateral heads of gastrocnemius Biceps femoris is on the lateral aspect and Sartorius muscle, gracilis muscle, semimembranosus muscle and semitendinosus tendon (medial to lateral) are on the medial aspect of the posterior part of the section. Popliteal artery and vein are between the heads of gastrocnemius with the vein being superficial. Posterolateral to the vein is the tibial nerve and on the medial aspect of biceps is the common peroneal nerve

Great saphenous vein is superficial to Sartorius and small saphenous vein is in the superficial fascia of the popliteal fossa.

TRANSVERSE SECTION OF THE LEG AT THE JUNCTION OF THE UPPER WITH THE MIDDLE THIRD (FIG. 31.4)

Due to the anterior border of tibia forming the projection of the shin and the medial surface being subcutaneous, the section at this level appears to be pentagonal with two borders sloping towards an anterior tip and three equal posterior borde s forming the rest of the pentagon. F bula appears to be posterolateral to tibia. Apart from the two leg bones, the rest of the area is filled with muscles. The interosseous membrane joining the two bones is clearly made out. Lying anterior to the membrane are the Tibialis anterior (medially) and the Extensor digitorum longus (laterally). The anterior tibial vessels (anterior tibial artery and its venae comitantes) lie between the two muscles. Peroneus longus is seen clinging to the fibula on the bone's anterior and lateral aspects. The deep peroneal nerve is usually seen between the Peroneus longus and the Extensor digitorum longus and the superficial peroneal nerve between the Peroneus longus and the anterior aspect of fibula.

Much of the section is occupied by the posterior leg muscles. Tibialis posterior is closely approximated to the posterior surface of the interosseous membrane between the two bones. Immediately posterior to this are the Flexor hallucis longus (laterally) and the Flexor digitorum longus. The hallucis muscle is larger and more fleshy than the digit muscle. Between the two muscles are the Posterior tibial vessels, peroneal vessels and the tibial nerve. Covering this stratum superficially is the bulky soleus, which appears V-shaped in section. Clothing the soleus still superficially are the two heads of gastrocnemius with a slender plantaris under the lateral head.

A few fibres of Popliteus muscle may frequently be seen at this level immediately posterior to the tibia.

Great and small saphenous veins are seen in the superficial fascia superficial to the medial and lateral heads of gastrocnemius respectively. The sural nerve is seen along with the small saphenous vein. Few other cutaneous veins may also be seen in the superficial fascia of the calf.

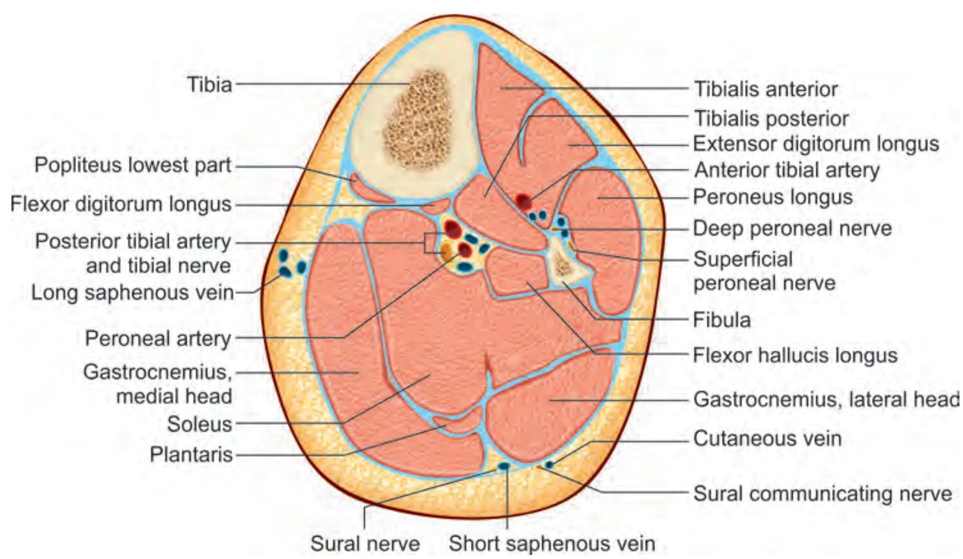


Fig. 31.4: Transverse through the left leg at the junction of upper with middle third (seen from below)

TRANSVERSE SECTION AT THE JUNCTION OF THE MIDDLE AND LOWER THIRD (FIG. 31.5)

In this section, the total mass of muscle appears to be less than the total mass of bones and connective tissue.

The two leg bones are prominent with a more prominent interosseous membrane. Approximated to the anterior surface of tibia is the fleshy Extensor hallucis longus. Superficial to this muscle are the tendons of Extensor digitorum longus (anterolaterally) and the Tibialis anterior (anteromedially). The anterior tibial vessels and the deep peroneal nerve are seen between the tibia and the Extensor hallucis longus. Peroneus tertius appears as a fleshy mass on the anterior aspect of the interosseous membrane. Peroneus longus (only the tendon at this level) and peroneus brevis have moved posteriorly and are seen posterolateral to fibula. Tibialis posterior and Flexor digitorum longus have also been reduced to tendons and are seen posterior to tibia. Flexor hallucis longus continues to be fleshy and is seen spanning most of the posterior aspects of fibula, interosseous membrane and tibia. Between the tendons of Tibialis posterior and Flexor digitorum longus medially and the Flexor hallucis longus laterally are the posterior tibial vessels and the tibial nerve. Tendocalcaneus is prominently seen in the most superficial posterior aspect of the section. A few fibres of soleus may still be seen on its underside. Great saphenous vein and the saphenous nerve are present in the medial superficial fascia and the small saphenous vein with the sural nerve in the posterior superficial fascia.

RADIOLOGICAL ANATOMY OF LOWER LIMB

Since the bones are radioopaque, disorders and problems involving the bones, joints and related structures are well analysed with the help of radiographs or X-rays.

As a radiographic picture is taken up of study, the following familiar steps should be gone through. The steps are:

- Identification of the area of the radiograph preferably with the concerned view (example, PA view, oblique view etc.);
- Identification of all the visible bony landmarks by name;
- Checking on the relations of the various bones and joints seen;
- Identification of the normal joint space;
- Identification of epiphyses if any

It is therefore imperative to notice and record any abnormality seen with regard to the aforementioned features.

Special and exclusive features of the concerned area should also be studied.

HIP REGION (FIG. 31.6)

A radiograph of the hip region usually shows the lower pelvis and the upper thigh.

Bones and Bony Landmarks

- Hip bone and its constituent parts like the ilium, ischium, pubis, acetabulum, the rami, the arcuate line of the pelvis, pubic symphysis and the ischial spine;
- Vertebral column and the constituent vertebrae, especially sacrum and coccyx;
- Femora and their upper ends including the heads, necks and trochanters.

Joints

Sacroiliac joints, vertebral joints, pubic symphysis and the hip joints; joint spaces (wherever applicable) should be noticed and widening of the space if any should be recorded.

Specific Features

- ***Neck-shaft angle of the femora*:** The angle is about 125 degrees in men and a little less in women; in children, the angle is more.

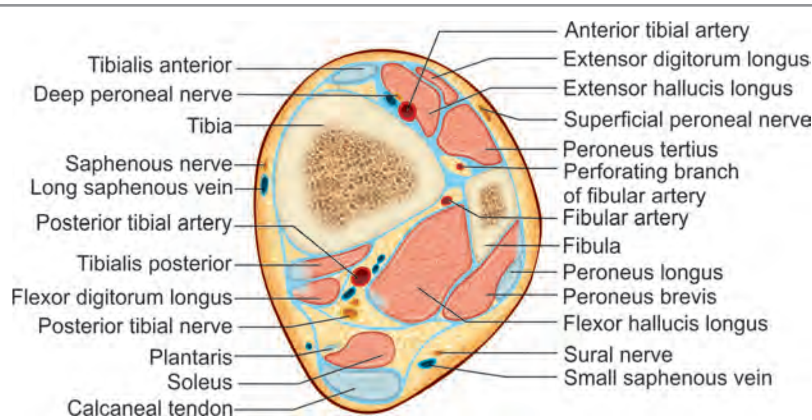


Fig. 31.5: Transverse section through the left leg at the junction of the middle and lower third (seen from below)

Fig. 31.6: Radiograph of the region of the hip joint in a ten year old boy. The three parts of the hip bone (ilium, ischium and pubis) are not fused to one another but the inferior ramus of the pubis is fused to the ischial ramus. Epiphyses for the head and greater trochanter of the femur are seen, separated from the diaphysis (which forms the shaft as well as the neck) by epiphyseal cartilages

- ***Shenton's line:*** A continuous curve formed by the upper border of Obturator foramen and the lower border of neck of femur.
- ***Fusion of conjoined ischiopubic ramus:*** The fusion between the two ramus of ischium and the inferior ramus of pubis occurs around the 7th year of age.

FEMUR BONE

The upper and lower ends of the bone articulate with other bones to form the hip and the knee joints respectively. The respective joint spaces are seen.

Two imaginary triangles are made out in the upper end. They are:

- ***Alsberg's triangle:*** An equilateral triangle formed by lines passing through the long axis of the shaft, the long axis of the neck and the base of the head;
- ***Ward's triangle:*** A wedge of cancellous bone near the base of head; changes in the dimensions and shape of the triangle indicate abnormality in position or relations of the structures concerned.

Secondary centres of ossification and non-fusion of epiphyses may be seen depending upon the age of the individual. As a corollary, age of the individual can be estimated with the help of the radiograph. This factor attains medico-legal importance.

KNEE REGION (FIG. 31.7)

Bones and Bony Landmarks

Lower end of femur with its condyles, upper end of tibia with its condyles and the tibial tuberosity, patella and upper end of fibula.

Joints

Knee joint with its joint space and superior tibiofibular joint.

In an anteroposterior view radiograph of the knee joint, the adductor tubercle is often seen above the medial condyle of femur. Femoral and tibial condyles are well made out; shadow of patella overlies the femur. The intercondylar area of tibia is seen in the joint space.

Patella (and fabella, if present) is seen clearly in a lateral view radiograph.

Specific Features

- *Presence of epiphyses in the lower end of femur and upper end of tibia* in young individuals.
- ***Bipartite patella:*** One of the upper angles is separate and has failed to fuse with the rest of the bone; sometimes, the separate part may itself be in many small parts, warranting the name 'multipartite patella'.

Fig 31.7: Radiograph of the region of the knee joint in a 10 year old boy. The unfused epiphyses for the lower end of the femur, the upper end of the tibia, and the upper end of the fibula are clearly seen. The shadow of the patella is seen as a lighter area overlapping the lower end of the femur

- ***Additional sesamoid bones:*** These may be seen where muscle tendons rub against bony areas. One of the regular sesamoid bones is the fabella which is seen under cover of the lateral head of gastrocnemius.

LEG BONES

Similar to the radiograph showing the femur, the radiograph showing the leg bones will also show the knee joint, proximal and distal tibiofibular joints and the ankle joint.

Joint spaces, presence of epiphyses, prominent bony markings will need to be studied.

ANKLE REGION AND FOOT (FIGS 31.8 AND 31.9)

A radiograph of the ankle region shows the tarsal bones too. If the talus and calcaneus are to be seen clearly, it is preferable to have a lateral view. Navicular and cuboid are seen clearly in both lateral and anteroposterior views. The cuneiforms, metatarsals and phalanges overlap each other in many views. They can be visualized in a dorsoplantar (superoinferior) view or an oblique view.

Specific Features

- ***Presence of sesamoids:*** Sesamoids are seen on the plantar aspect of the head of first metatarsal bone. Rarely, sesamoids are seen under cover of any of the tendons in the sole.

IMPORTANT LINES AND AREAS

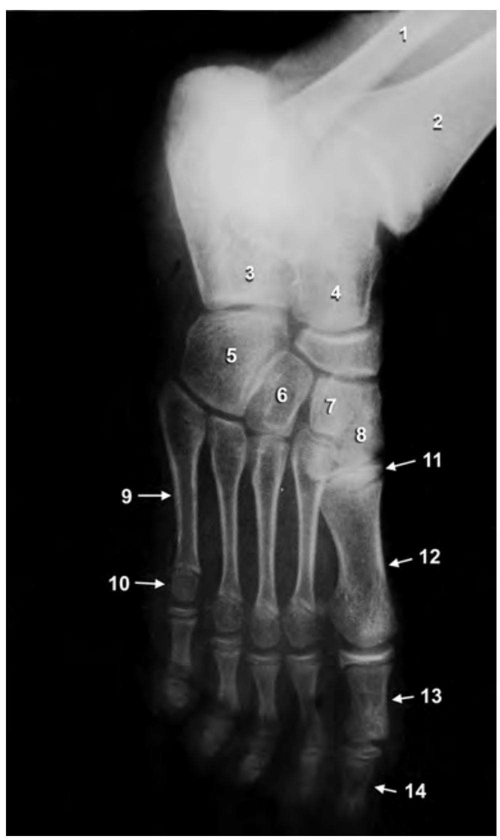
Some areas are marked by imaginary lines, spaces and points. It is necessary to know such areas during examination of patients as many of these areas indicate important structures.

- ***Bryant's triangle:*** Otherwise called the iliofemoral triangle, the triangle is drawn as under:
  - Line A: Drawn around the body at the level of anterior superior iliac spines;
  - Line B: Drawn perpendicular to line A, connecting line A and the greater trochanter of femur;
  - Line C: Drawn from the trochanter to the anterior superior iliac spine, thus completing the triangle.

The triangle is drawn on both sides and compared. In cases of femoral fractures and hip dislocations, the distance

1. Shaft of tibia
2. Shaft of fibula
3. Lower fibular epiphysis
4. Lower tibial epiphysis
5. Talus

Fig. 31.8: Radiograph of the region of the ankle in a 10 year old boy. Unfused epiphyses for the lower end of the tibia and fibula are clearly seen. The outline of the upper part of the talus is clear but other tarsal bones cannot be demarcated because of overlap of their shadows



1. Lower end of fibula
2. Lower end of tibia
3. Calcaneus
4. Talus
5. Cuboid bone
6 Lateral cuneiform bone
7. Intermediate cuneiform bone
8. Medial cuneiform bone
9. Fifth metatarsal
10. Epiphysis of fifth metatarsal
11. Epiphysis of first metatarsal
12. Shaft of first metatarsal
13. Proximal phalanges with epiphyses at their proximal ends
14. Middle phalanges with epiphyses at their proximal ends

Fig. 31.9: Radiograph showing the skeleton of the foot in a 10 year old boy. Identify the tarsal bones, the metatarsal bones, and the phalanges. The second to fifth metatarsal bones show unfused epiphyses at their distal ends. In the first metatarsal the epiphysis is located at the proximal end. Epiphyses are also seen at the proximal ends of each of the phalanges, but the distal phalanges are not seen clearly in this skiagram

between line A and the greater trochanter (measured by the length of line B and is called the supratrochanteric distance) is reduced because of an upward displacement of the greater trochanter. The triangle is used as a diagnostic tool in orthopaedics.

- ***Langenbeck's triangle:*** A triangular area marked by lines connecting the anterior superior iliac spine, surface of greater trochanter and the middle of the neck of femur. Any penetrating or deep wound in this triangle will go through the joint.
- ***Weber's triangle:*** A triangular area on the sole; formed by lines joining the head of first metatarsal, head of fifth metatarsal and the centre of the plantar aspect of the heel.
- ***Bryant's line:*** Line B of the Bryant's triangle; the line along which the greater trochanter moves in dislocations and fractures.
- ***Feiss line:*** A curved line from the tip of medial malleolus to the plantar aspect of the first metatarsophalangeal joint.
- ***Holden's line:*** The shallow transverse furrow seen in the groin region, that starts at the pubic tubercle and runs laterally for about 8 cm; the lateral extent of this line passes outward between the anterior superior iliac spine (superiorly) and the greater trochanter (inferiorly); this line indicates the line of fusion of superficial and deep faciae of upper thigh and the capsule of the hip joint.
- ***Lanz's line:*** Commonly called the interspinal line; the horizontal line connecting the two anterior superior iliac spines.
- ***Meyer's line:*** Line passing through the long axis of big toe and the midpoint of the heel.
- ***Nelaton's line:*** The line drawn from the anterior superior iliac spine to the tuberosity of ischium; normally, the greater trochanter lies on this line; in hip dislocations and in femoral fractures, the greater trochanter is felt above this line and so serves as an indicator for diagnosis.
- ***Roser-Nelaton line:*** Same as Nelaton's line.
- ***Inter cristal line:*** The line joining the highest points of the iliac crests. This line crosses the intervertebral disc between L4 and L5 vertebrae (and the level of the L4 spine) and indicates the middle of the lumber cistern. This is a very useful landmark while doing a lumber puncture.
- ***Posterior iliac spinous line:*** The line joining the posterior superior iliac spines or as seen on the surface, the line joining the dimples which indicate the posterior superior iliac spines. This line indicates the S2 spine, middle of sacro iliac joints, bifurcation of common iliac arteries and the lowest limit of the dural.

SUPERNUMERARY BONES OF LOWER LIMB

Some additional bones may be found in the lower limb. These are small in size and hence called supernumerary ossicles. The commonest ossicles are:

- ***Os trigonum:*** Separate lateral tubercle of talus;
- ***Os tibiale externum:*** Separate navicular tuberosity;
- ***Bipartite medial cuneiform*** In separate upper and lower halves;
- Small ossicle in Peroneus longus tendon lateral to cuboid;
- *Sesamoid bone* in Tibialis posterior tendon;
- ***Os vesalianum:*** Separate tuberosity of fifth metatarsal

SURFACE MARKING OF IMPORTANT BONY POINTS AND STRUCTURES OF LOWER LIMB

BONY POINTS AND PLANES

- ***Midinguinal point:*** It is the point midway between the anterior superior iliac spine and the pubic symphysis.
- ***Midpoint of inguinal point:*** It is the point midway between the anterior superior iliac spine and pubic tubercle.
- ***Highest Point of the iliac crest:*** It is at the level of the space between the spines of L3 and L4 vertebrae.
- ***Tubercle of the iliac crest:*** A point 5 cm behind the ASIS along the outer margin of iliac crest indicates the tubercle of the iliac crest; the horizontal plane passing through this is the ***transtubercular plane*** and corresponds to L5 vertebral spine.
- ***Coccyx:*** It is palpated in the superior part of the intergluteal cleft.
- ***Centre of the femoral head***: A point about a thumb's breadth below the midpoint of inguinal ligament indicates the centre of femoral head.
- ***Femoral condyles:*** These are readily palpated, especially when the knee is flexed. The epicondyles are felt as prominences over the condyles.
- ***Adductor tubercle:*** The medial condyle of the femur is palpated. Then by pressing downwards, backwards and laterally on the medial condyle the adductor tubercle can be felt. It is about 1 cm above the medial epicondyle.
- ***Greater Trochanter:*** It is the prominence anterior to the hollow on the lateral aspect of gluteal region. It can be marked 10 cm below the iliac crest. A line joining the tips of the two greater trochanters passes through the pubic tubercles and the centres of femoral heads in the anatomical position.
- ***Tuberosity of tibia:*** It is readily palpated on the anterior aspect of upper tibia, about 5 cm distal to apex

of patella. It indicates the level of head of fibula and the bifurcation of popliteal artery into anterior and posterior tibial arteries.

- ***Head of talus:*** A point in the middle of a line joining the tip of medial malleolus and the tuberosity of the navicular bone indicates the head of talus.

VESSELS

- ***Femoral artery:*** A broad line is drawn connecting the midinguinal point and the adductor tubercle. The upper two-third of this line marks the femoral artery. The upper third of the line represents the artery in the femoral triangle and the middle third represents the artery in the adductor canal.
- ***Femoral vein:*** Point A is marked 1 cm medial to the midinguinal point. Point B is marked 1 cm lateral to the adductor tubercle. The upper two third of a line joining these two points marks the femoral vein. The vein is medial to the artery in the upper part, posterior to the artery in the middle part and lateral to the artery in the lower part.
- ***Descending genicular and saphenous branches of femoral artery:*** The lower third of the line joining the midinguinal point and the adductor tubercle marks the descending genicular and saphenous branches of the femoral artery.
- ***Profunda femoris artery:*** Step 1 – The femoral artery is marked on the surface. Step 2 – Two more points are marked. Point A is marked 3.5cm below the midinguinal point. Point B is marked 10 cm below the midinguinal point. The two points are joined by a line which is convex laterally. Point B is a little lateral to the line of femoral artery. The curved line connecting points A and B indicates the profunda femoris artery branching off the femoral artery.
- ***Superior gluteal artery:*** Point A is marked at the centre of the dimple over the posterior superior iliac spine. Point B is marked at the apex of the greater trochanter. The point of junction between the medial third and the lateral two-thirds of the line joining the two points indicates the entry point of superior gluteal artery into the gluteal region.
- ***Inferior gluteal artery:*** Point A is marked at the centre of the dimple over the posterior superior iliac spine. Point B is marked on the ischial tuberosity. The two points are joined by a line. Point C is marked 2.5 cm lateral to the midpoint of this line. Yet another point D, 1 cm medial to point C is marked. This point D indicates the entry point of inferior gluteal artery into the gluteal region.
- ***Popliteal artery:*** Point A is marked at the junction of the middle and the lower thirds of the thigh, on the back of the limb, 2.5 cm medial to the midline. Point B is marked on the midline right at the back of knee. Point C is marked on the midline, at the level of tibial tuberosity on the back of leg. Points A and B are joined by a line which is concave medially in its upper part; then the line runs vertically down and continues to connect points B and C. The entire line should be 0.75 to 1 cm in width and indicates the popliteal artery through its course.
- ***Anterior Tibial artery:*** Point A is marked 2.5 cm below the medial side of the head of fibula on the anterior aspect of upper leg. Point B is marked midway between the medial and the lateral malleoli on the anterior aspect of ankle. A broad line that runs downward and medially connecting these two points indicates the anterior tibial artery.
- ***Dorsalis pedis artery:*** Point A is marked midway between the two malleoli on the anterior aspect of the ankle Point B is marked on the proximal end of the first intermetatarsal space. The line on the dorsum of foot connecting these two points indicates the dorsalis pedis artery.
- ***Great arterial trunk of cruris:*** This name is given to the anterior tibial and the dorsalis pedis arteries put together. A continuous line joining a point 2.5 cm below the medial side of the head of fibula on the anterior leg to another point on the proximal end of the first intermetatarsal space, through a point midway between the two malleoli on the anterior aspect of ankle indicates the great arterial trunk.
- ***Posterior Tibial artery:*** Point A is marked on the inferior angle of popliteal fossa at the level of neck of fibula. Point B is marked midway between the medial malleolus and the most prominent part of heel on the medial aspect of the foot. A broad line connecting these two points indicates the posterior tibial artery.
- ***Bifurcation of Posterior tibial artery:*** A point midway between the medial malleolus and the most prominent part of heel on the medial aspect of the foot indicates the bifurcation of the posterior tibial artery.
- ***Medial plantar artery:*** Point A is marked midway between the medial malleolus and the prominence of the heel on the medial aspect of the foot. Point B is marked on the first interdigital cleft on the plantar aspect. The proximal half of the line joining these two points marks the medial plantar artery.
- ***Lateral plantar artery:*** Point A is marked midway between the medial malleolus and the prominence of the heel on the medial aspect of the foot. Point B is marked 2.5 cm medial to the tuberosity of the fifth metatarsal bone on the plantar aspect. A line joining the two points marks the lateral plantar artery.

- ***Plantar arch:*** Point A is marked 2.5 cm medial to the tuberosity of the fifth metatarsal bone on the plantar aspect. Point B is marked at the proximal end of the intermetatarsal space, at a level which is 2.5 cm distal to the tuberosity of the navicular bone. The two points are joined by a line which is convex forward and this line marks the plantar arch.
- ***Great saphenous vein:*** Though the vein is readily visible in most individuals, it may be necessary to mark it in certain diseases and in treatment conditions. Point A is marked at the medial end of the dorsal venous arch on the dorsum of foot. Point B is marked on the anterior border of the medial malleolus. Point C is marked on the medial border of tibia at the level of the junction of the middle and lower thirds of the leg. Point D is marked at the adductor tubercle Point E is marked at the saphenous opening. Points A, B and C are joined by a line running upwards with a slight medial convexity. Points C and D are joined by a line that has curves over the femoral condyles. Points D and E are joined by a line that inclines laterally.
- ***Small saphenous vein:*** This vein is easily visible in its lower part. Point A is marked at the lateral end of the dorsal venous arch on the dorsum of foot. Point B is marked immediately behind the lateral malleolus. Point C is marked anterior to the tendocalcaneus on the lateral aspect, about 1.5 cm above the lateral malleolus. Point D is marked in the midline on the back of leg at the level of the middle of popliteal fossa. A line joining all these points will indicate the small saphenous vein.

NERVES

- ***Femoral nerve:*** Point A is marked 1.25 cm lateral to the midinguinal point. Point B is marked 2.5 cm inferior to point A in the same vertical line. A broad line joining the two points marks the femoral nerve.
- ***Sciatic nerve in gluteal region:*** Point A is marked 2 cm lateral to the midpoint of a line joining the posterior superior iliac spine and the ischial tuberosity. Point B is marked midway between the ischial tuberosity and greater trochanter. A broad band (with a lateral convexity) connecting these two points indicates the gluteal part of the sciatic nerve.
- ***Sciatic nerve in thigh:*** Point A is marked midway between the ischial tuberosity and greater trochanter. Point B is marked at the superior angle of popliteal fossa. A broad band connecting these two points indicates the sciatic nerve in the back of thigh.
- ***Tibial nerve in popliteal fossa:*** Point A is marked at the superior angle of popliteal fossa. Point B is marked in the midline on the back of leg at the level of tibial tuberosity. A line connecting these two points indicates the course of tibial nerve in the popliteal fossa.
- ***Tibial nerve in the back of leg:*** Point A is marked in the midline on the back of leg at the level of tibial tuberosity. Point B is marked on the posteromedial aspect of the ankle midway between the medial malleolus and the tendocalcaneus. A line joining the two points and is also inclined medially indicates the tibial nerve in the posterior compartment of leg.
- ***Common Peroneal nerve:*** Point A is marked at the superior angle of popliteal fossa Point B is marked on the back of the head of fibula The two points are joined by a line that runs along the tendon of biceps femoris and this line indicates the common peroneal nerve.
- ***Deep Peroneal nerve:*** Point A is marked on the lateral side of the neck of fibula. Point B is marked on the anterior aspect of the ankle, midway between the two malleoli. A line joining the two points indicates the deep peroneal nerve in the anterior compartment of leg. The line should have a mild lateral concavity in its upper third but run vertically down in the remaining two-thirds. A line closely parallel but lateral to the dorsalis pedis artery will mark the medial terminal branch of the deep peroneal nerve.
- ***Superficial peroneal nerve:*** Point A is marked on the lateral aspect of the neck of fibula. Point B is marked on the anterior border of peroneus longus at the junction of the upper two thirds with the lower third of the leg. A line connecting the two points indicates the superficial peroneal nerve. Point B also indicates the point at which the nerve pierces the deep fascia.
- ***Medial plantar nerve:*** Point A is marked midway between the medial malleolus and the prominence of the heel on the medial aspect of the foot. Point B is marked on the first interdigital cleft on the plantar aspect. The proximal half of the line joining these two points indicates the medial plantar nerve. When the medial plantar artery and the nerve are marked, the nerve should be marked lateral to the artery.
- ***Lateral plantar nerve:*** Point A is marked midway between the medial malleolus and the prominence of the heel on the medial aspect of the foot. Point B is marked 2 5 cm medial to the tuberosity of the fifth metatarsal bone on the plantar aspect. A line joining the two points marks the lateral plantar nerve. When the lateral plantar artery and the nerve are marked, the nerve should be marked medial to the artery.
- ***Deep branch of the lateral plantar nerve:*** It should be marked the same as plantar arch. The nerve is medial to the arch.

OTHERS

- ***Sacroiliac joints:*** The skin dimple of PSIS; the dimple is seen about 4 cm lateral to the midline in the gluteal region (the dimple is also the surface landmark of PSIS

and is formed because of the skin and fascia being attached to the PSIS).

- ***Inferior border of Gluteus maximus muscle:*** A line connecting the coccyx and the ischial tuberosity denotes the inferior border of the muscle.
- ***Superior border of Piriformis muscle:*** A line joining the skin dimple of posterior superior iliac spine and the superior border of greater trochanter indicates the superior border of this muscle.
- ***Saphenous opening:*** A point 4 cm inferior and 4 cm lateral to the pubic tubercle is taken. An elliptical marking with the long axis running inferolaterally with a length of 2.5 cm and a breadth of 2 cm marks the opening.
- ***Femoral ring:*** A horizontal line that is 1.25 cm long over the medial part of inguinal ligament, 1.25 cm medial to the midinguinal point marks the femoral ring.
- ***Superior extensor retinaculum:*** The retinaculum is marked after marking the medial and lateral borders. The medial border is marked on the lower part of the anterior border of tibia with a slight medial inclination for a vertical breadth of 3 cm. The lateral border is marked on the anterior border of the triangular subcutaneous of fibula for the same breadth The two borders are united by a broad band that has a vertical breadth of 3 cm and indicates the superior extensor retinaculum of leg.
- ***Inferior extensor retinaculum:*** Due to the shape of this retinaculum, a stem and two bands need to be marked.
  - Stem: The lateral border is marked on the anterior aspect of the upper surface of calcaneus; the medial border is marked on the anterior aspect as the leg turns to the dorsum, immediately medial to the tendon of extensor digitorum longus; The two borders are joined by a band that is 1.5 cm broad. This band indicates the stem of the inferior retinaculum.
  - Superior band: The lateral border is the medial border of the stem; the medial border is marked on the anterior border of medial malleolus; the two are connected by a band of line about 1 cm in breadth. The band indicates the superior band of the inferior retinaculum.
  - Inferior band: The lateral border is the medial border of the stem; the medial border is marked on the medial side of the foot running straight down to the sole; the two borders are joined by a band of about 1 cm breadth and the band indicates the inferior band of the inferior retinaculum.
- ***Flexor retinaculum:*** The lateral border is marked running downwards and forwards across the medial malleolus. The medial border is marked on the medial aspect of the prominence of the heel. The two borders are joined by a band that is 2 5 cm in breadth. This band indicates the flexor retinaculum.

Clinical Correlation

Places where Pulsations can be Felt

- ***Anterior tibial artery:*** On the anterior aspect of ankle midway between the two malleoli.
- ***Dorsal s pedis artery:*** On the dorsum of foot, over the first intermetatarsal space.
- ***Posterior tibial artery:*** About a finger's breadth below and behind the medial malleolus; the foot should be slightly inverted passively to feel the pulse clearly.

MAKING TENDONS OF MUSCLES PALPABLE

During the course of examination of a patient, it may be necessary to make certain tendons prominent, so as to palpate them and the related areas.

- ***Tibialis anterior tendon:*** When the foot is inverted and dorsiflexed, the tendon can be seen and felt as it runs medially over the anterior aspect of ankle.
- ***Extensor hallucis longus:*** If the great toe is also dorsiflexed in the above said position, tendon of extensor hallucis longus can be felt lateral to the tibialis anterior tendon.
- ***Extensor digitorum longus:*** When the toes are extended, the tendinous slips of extensor digitorum longus can be palpated on the dorsum of foot.
- ***Peroneus longus and brevis:*** When the foot is everted and dorsiflexed, these tendons can be palpated behind the lateral malleolus.
- ***Gastrocnemius and soleus:*** When the individual stands on toes, these muscles are readily seen and felt.
- ***Tibialis posterior:*** When the foot is actively inverted, the tendon of tibialis posterior can be felt behind and below the medial malleolus.

Multiple Choice Questions

1. The tendon of Tibialis anterior can be best visualized when
   a. The foot is inverted and plantar flexed
   b. The great toe is dorsiflexed
   c. The great toe is dorsiflexed and other toes are abducted
   d. The foot is inverted and dorsi flexed

2. The transtubercular plane corresponds to
   a. L5 spine
   b. L4 spine
   c. S1 spine
   d. S2 spine

3. The supernumerary ossicle called Os tibiale externum is
   a. Broken medial malleolus
   b Separate navicular tuberosity
   c. Sesamoid bone under Tibialis posterior tendon
   d. Avulsed medial cuneiform

4. A deep wound in the langenbeck's triangle can go through the
   a Knee jont
   b. Hip joint
   c. First inter digital cleft
   d. Popliteal fossa

5. The cross section of leg at the junction of upper and middle thirds of leg appears pentagonal because
   a. The anterior border of tibia projects as shin
   b. Bulky muscles on the posterior aspect cause three flat sides
   c. The section goes through the lower part of knee joint
   d. Interosseous membrane creates a dynamic muscular symmetry

ANSWERS

1. d **2.** a **3.** c **4.** b **5.** a

Clinical Problem-solving

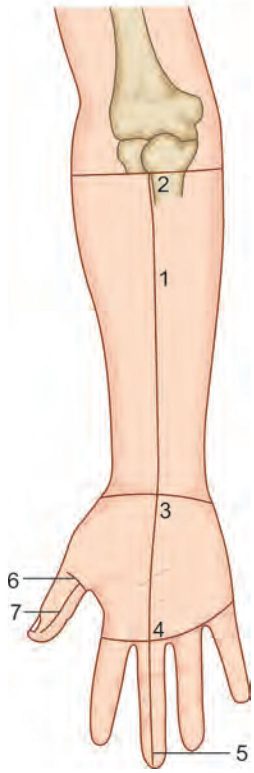
Case Study 1: You are given the CT picture of the right knee joint above the patella.
- Apart from the knee joint, what are the important regions will you be able to see?
- What are the neurovascular structures you would look for?
- What is the bone seen and what are the muscles seen on its anterior aspect?

Case Study 2: A radiograph of a right femur is given to you.
- What features would you attempt to study?
- If you are asked to deduce the age of the individual, what would you specifically look for?

(For solutions see Appendix).

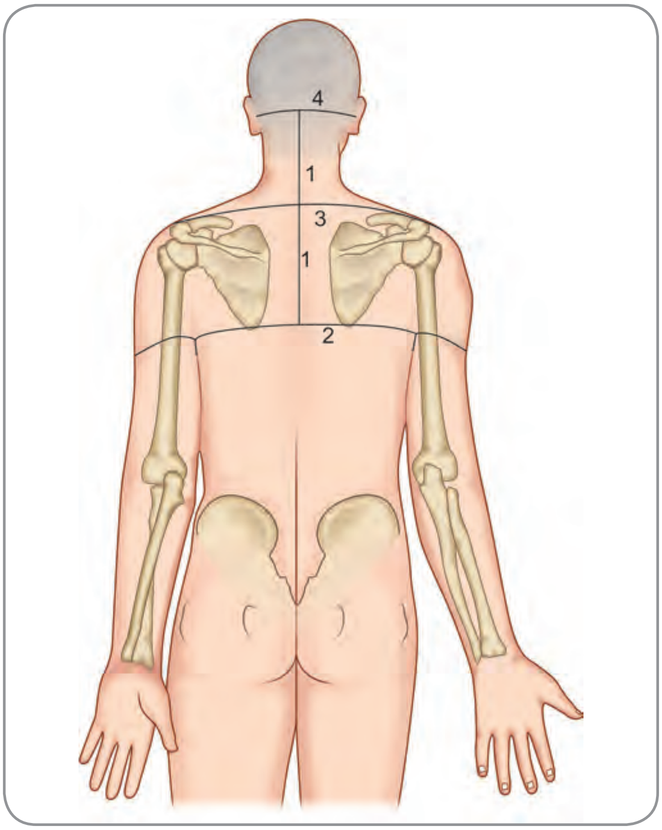
Appendices

SKIN INCISIONS FOR FRONT OF FOREARM AND PALM



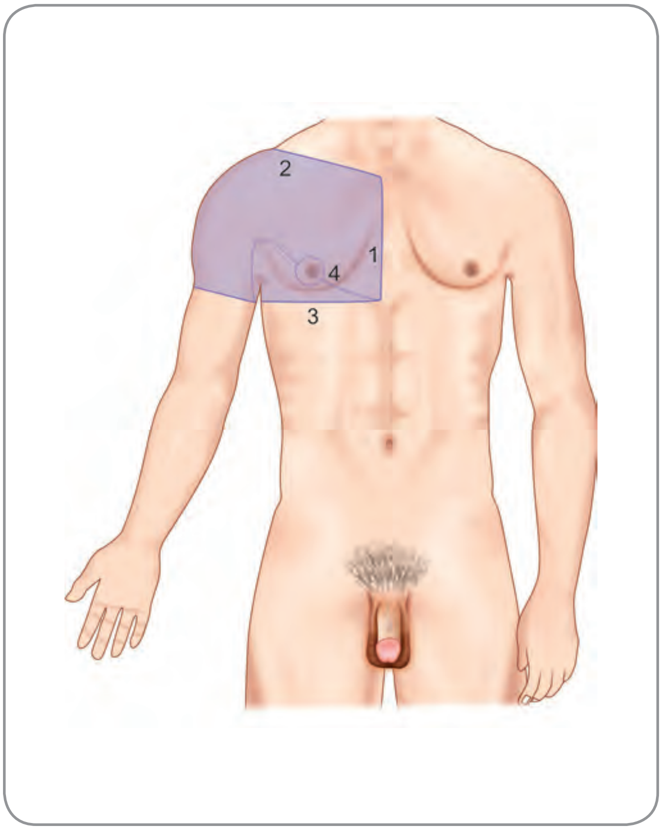
1. Longitudinal incision on midline of flexor surface of forearm
2. Transverse incision at upper end of longitudinal incision
3. Transverse incision at distal carpal crease. This incision will serve as the lower incision for exposure of forearm and as upper incision for exposure of palm
4. Transverse incision along bases of fingers
5. Longitudinal incision along middle finger
6. Small transverse incision at the base of thumb
7. Longitudinal incision along thumb

SKIN INCISIONS FOR BACK AND SCAPULAR REGION



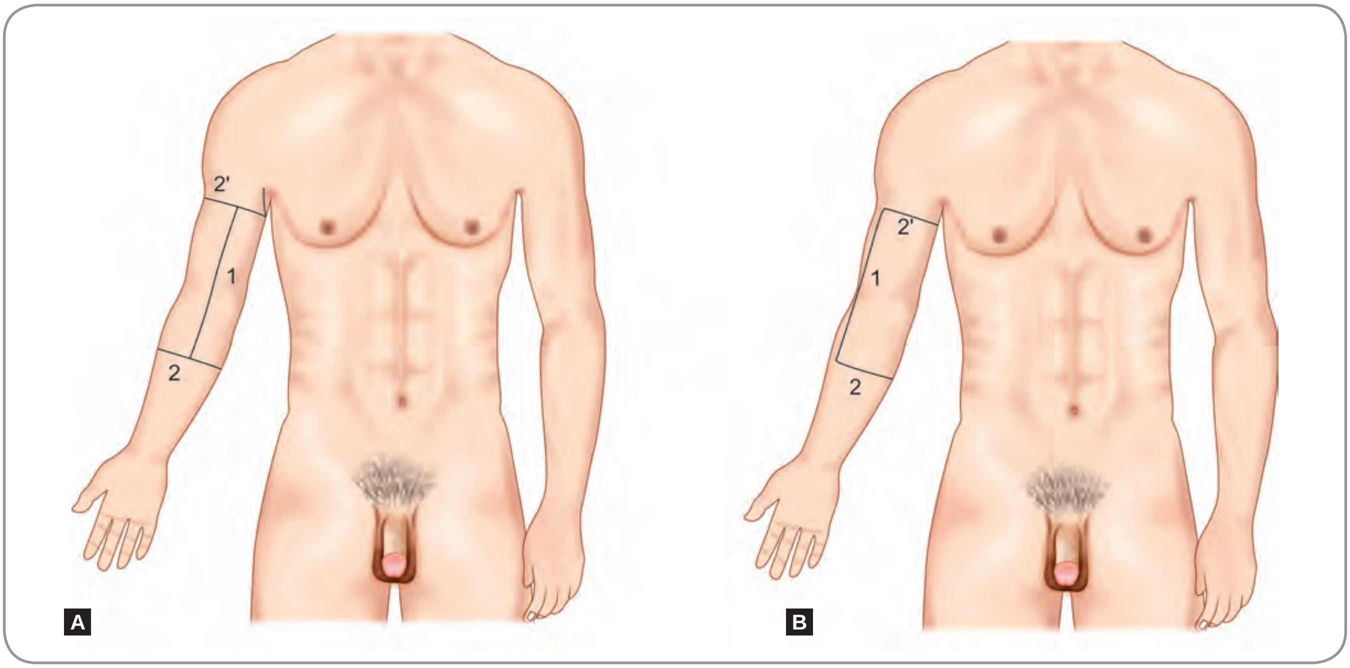
1. Vertical incision from external occipital protuberance to the level of inferior scapular angle
2. Transverse incision to the lateral aspect of trunk
3. Transverse curved incision till the acromion
4. Transverse incision from external occipital protuberance to the base of mastoid

SKIN INCISIONS FOR PECTORAL REGION AND AXILLA



1. Midline incision from jugular notch to xiphisternal junction
2. From jugular notch to acromion along the clavicle
3. Transverse incision from xiphisternal junction to the lateral part of trunk
4. From xiphisternal junction to the medial aspect of arm through the anterior axillary fold

TWO TYPES OF SKIN INCISIONS FOR FRONT OF ARM AND CUBITAL FOSSA



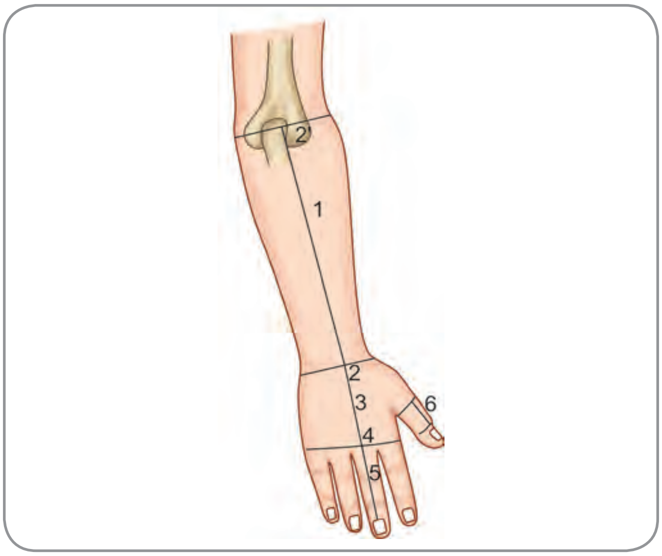
A. 1. Vertical incision from the level of midarm to the junction of upper and middle thirds of forearm

2 & 2'. Transverse incisions at the upper and lower limits of the vertical incision

B. The two transverse incisions remain the same.

1. Vertical incision is made along the lateral border of arm and forearm

SKIN INCISIONS FOR BACK OF FOREARM AND DORSUM OF HAND



1. Longitudinal incision along the midline of the dorsal aspect of forearm

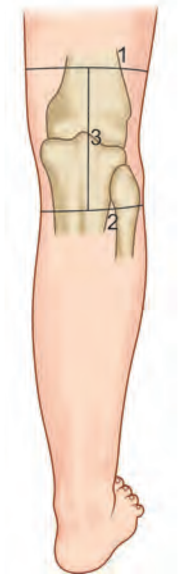
2 & 2'. Transverse incisions at the upper and lower limits of the longitudinal incision

3 & 5. Extensions of the longitudinal incision into the dorsum and middle finger

4. Transverse incision at the bases of fingers

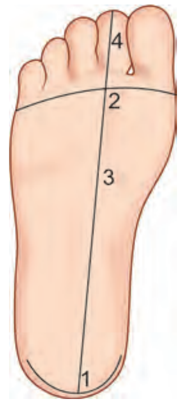
6. Incisions which can be made to study the thumb

SKIN INCISIONS FOR POPLITEAL FOSSA



1. Transverse incision at the level of superior border of patella
2. Transverse incision at the level of tibial tuberosity
3. Vertical incision on the midline connecting the two transverse incisions

SKIN INCISIONS FOR SOLE OF FOOT

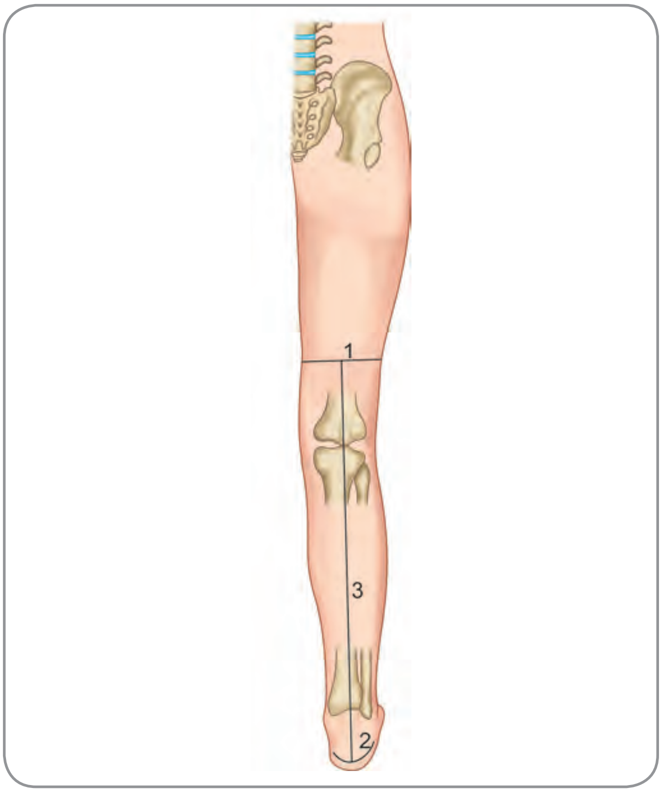


1. Transversely curved incision at heel
2. Transverse incision at the bases of toes
3. Longitudinal incision connecting the two transverse incisions
4. Longitudinal incision that can be extended into the second toe

SKIN INCISIONS FOR FRONT OF THIGH AND MEDIAL ASPECT OF THIGH

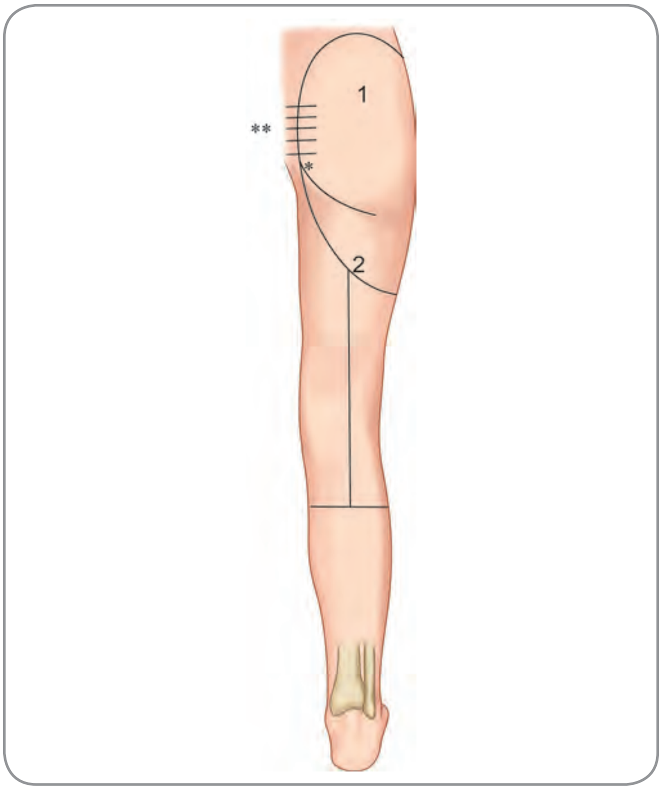
1. Curved incision from ASIS to pubic tubercle
2. Transverse incision at the level of tibial tuberosity
3. Longitudinal incision connecting the two transverse incisions along the medial border of the thigh

SKIN INCISIONS FOR BACK OF LEG



1 Transverse incision at the junction of middle and lower thirds of thigh
2. Transverse incision on distal heel
3. Vertical incision along the midline on the posterior aspect of thigh and leg

SKIN INCISIONS FOR GLUTEAL REGION AND BACK OF THIGH

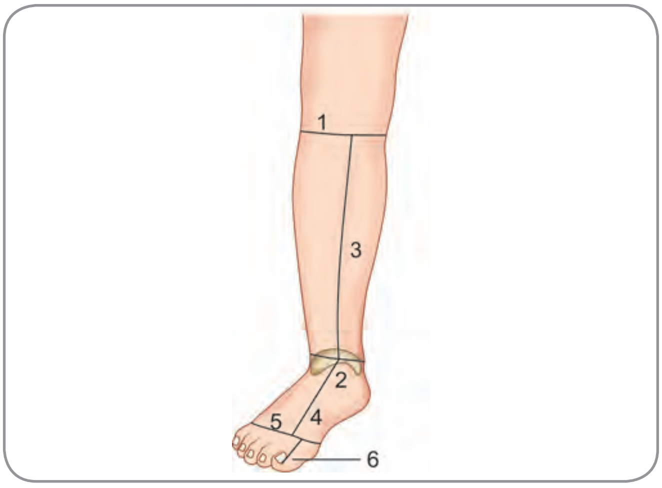


1. Curved incision from natal cleft to lateral aspect of trunk
2. Curved incision from medial tip of transverse gluteal fold to the lateral border of the lower limb

3 & 4. Longitudinal and transverse incisions which can be made, if required to expose the back of thigh and popliteal fossa

* gluteal fold   ** natal cleft

SKIN INCISIONS FOR FRONT OF LEG AND DORSUM OF FOOT



1. Transverse incision at the level of ligamentum patellae
2. Transverse incision at the level of malleoli
3. Vertical incision along shin, deviating to midline in the lower part
4. Extension of vertical incision into the dorsum in line with the axis line of second toe
5. Transverse incision along the bases of toes
6. Incision into big toe, if required, to study the big toe

SOME FREQUENTLY USED NAMES AND THEIR PLURAL FORMS

Gluteus maximus	Glutei maximi
Gluteus minimus	Glutei minimi
Gluteus medius	Glutei medii
Pectineus	Pectinei
Obturator externus	Obturatores externi
Obturator internus	Obturatores interni
Gemellus	Gemelli
Vastus	Vasti
Gastrocnemius (pronounced gastroneemiyas; 'c' is silent)	Gastrocnemii
Popliteus	Poplitei
Gracilis	Graciles (pronounced grasuleez)
Sartorius	Sartorii
Soleus	Solei
Tibialis anterior	Tibiales anteriores (pronounced tibialeez anteeriyores)
Tibialis posterior	Tibiales posteriores (pronounced tibialeez posteeriyores)
Interosseous	Interossei
Peroneus	Peronei
Biceps Bicep (incorrect English adaptation)	Biceps (correct English form) Bicepses (accepted English form) Bicipites (correct Latin form)
Triceps Tricep (incorrect English adaptation)	Triceps (correct English form) Tricepses (accepted English form) Tricipites (correct Latin form)
Quadriceps	Quadriceps Quadricepses (rarely accepted English form) Quadricipites (correct Latin form)
Rectus	Recti
Psoas	Psoai (pronounced so-ay) Psoae (pronounced so-ee) Psoas
Iliacus	Iliaci
Adductor longus	Adductores longi
Adductor brevis	Adductores breves
Adductor magnus	Adductores magna
Abductor(as used in a muscle name)	Abductores
Adductor (as used in a muscle name)	Adductores
Abductor (as used generally)	Abductors
Adductor (as used generally)	Adductors
Brevis (as used in names of muscles)	Breves (pronounced breveez)
Breve (pronounced brevi)(as used in Vinculum breve)	Brevia
knee	Knees Kneen (rarely used English form)
Piriformis	Piriformis Piriformii (rarely used correct form)
Hernia	Herniae
Tendocalcaneus	Tendocalcanei

TECHNICAL TERMS AND THEIR USAGE

Meaning/Used as	Singular	Plural
Semilunar cartilage	Meniscus	Menisci
Horn	Cornu	Cornua
Thigh bone	Femur	Femora
Arm bone	Humerus	Humeri
Forearm lateral bone	Radius	Radii
Forearm medial bone	Ulna	Ulnae
Leg medial bone	Tibia	Tibiae
Leg lateral bone	Fibula	Fibulae
Part of hip bone	Ilium	Ilia
Part of hip bone	Ischium	Ischia
Shoulder blade	Scapula	Scapulae
Col ar Bone	Clavicle	Clavicula
Cup shaped bony girdle at the lower end of trunk	Pelvis	Pelves (pronounced pelveez); 'pelvises' s also colloquially used
Part of hip bone	Pubis (pronounced pyubis or pyubez)	Pubes (pronounced pyubeez)
Bones of the wrist region	Carpus	Carpi
Bones of the ankle region	Tarsus	Tarsi
Knee cap	Patella	Patellae
Heel bone	Calcaneus	Calcanei or Calcanea
Ankle bone	Talus	Tali Taluses (incorrect colloquial usage)
Bones of foot	Metatarsus	Metatarsi
Bones of hand	Metacarpus	Metacarpi
Bone of Finger/Toe/Digit	Phalanx	Phalanges
Bony prominence	Malleolus	Malleoli
Partition	Septum	Septa, septae
Fibrous sheath	Retinaculum	Retinacula
Small pouch of synovial fluid	Bursa	Bursae
Opening	Foramen	Foramina
Small eminence	Tubercle	Tubercles (Tubercula in old style)
Eminence or prominence	Tuberosity	Tuberosities
Small or shallow depression	Fossa	Fossae
Fibrous cord or band	Ligament	Ligaments
Network	Plexus	Plexuses
Branch or extension	Ramus	Rami
Groove or fissure	Sulcus	Sulci
Small pit	Fovea	Foveae (pronounced foveeyae)
Bony prominence	Trochanter	Trochanters
Hollow space or cavity	Sinus	Sinus or sinuses
Growing embryo	Foetus	Foetus or Foetuses
Out pouching	Diverticulum	Diverticula
Bunch or Collection	Ganglion	Ganglia
Fibrous layer or sheet	Fascia	Fasciae
Venous blood vessel	Vein	Veins
Venous blood vessel	Vena	Venae
Large vein	Vena cava	Venae cavae
Accompanying vein	Vena comitans	Venae comitantes or Vena comitantes
Meshwork of blood vessels	Anastomosis	Anastomoses (pronounced anastomosus or anastomosees)
Stalk or Pedicel or leg	Crus	Crura
Flat tendinous structures or fascial sheaths	Aponeurosis	Aponeuroses (pronounced aponeurosees)

Index

Page numbers followed by *f* refer to figure and *t* refer to table.

C

K

L

R

S

T

U

V

W